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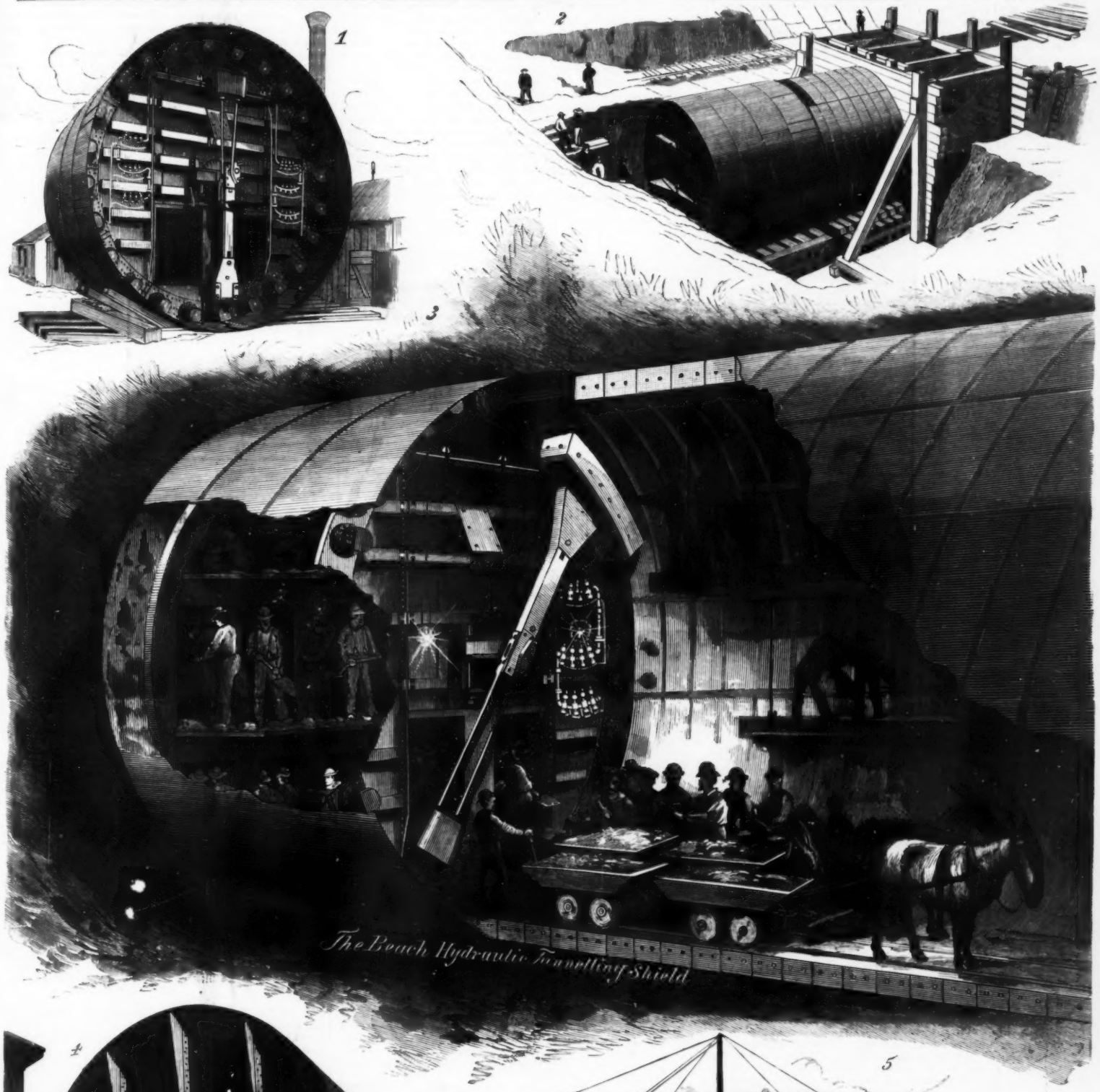


Fig. 1.—Rear view of the shield, showing hood and rams. Fig. 2.—The shield in place on grade. Fig. 3.—Interior view of shield and tunnel. Fig. 4.—Front view of shield. Fig. 5.—Lowering of the shield to the heading.

THE BEACH HYDRAULIC SHIELD AT WORK IN THE GREAT RAILWAY TUNNEL UNDER THE ST. CLAIR RIVER BETWEEN THE UNITED STATES AND CANADA.

THE GREAT RAILWAY TUNNEL UNDER THE ST. CLAIR RIVER, BETWEEN THE UNITED STATES AND CANADA.

Owing to the steady increase of traffic over the Grand Trunk R.R. of Canada and the Chicago and Grand Trunk, Detroit, Grand Haven and Milwaukee, and the Toledo, Saginaw and Muskegon Railroads of the United States (practically one company) during the last few years, it became obvious that some other means of transit other than the steam car ferry now in operation would be necessary, as that method is a great annual expense, and is also very unreliable, especially so in the winter, when the ice in Lake Huron becomes loose and is carried down the St. Clair River, after catching the ferry boat and carrying it down the river with its cargo of passengers or freight. This necessitates the maintenance of a powerful tug, always in steam, and ready to go at a moment's notice to aid the ferry and break the ice if necessary.

Owing to the extreme flatness of the country, and the low-lying ground in that part of the country, it was found impracticable to build a bridge, in consequence of the great height to which it would have to be carried, to allow of free navigation, as the traffic at this point is very great, and the current very swift, viz., eight miles an hour. So the construction of a tunnel was decided upon.

The St. Clair Tunnel Co. was formed in the year 1886, and late in the fall of that year operations were commenced on the test shafts on both sides of the river, and were carried to a depth of 92 feet on the United States side of the river and 98 feet on the Canadian side. They were 4 feet by 8 feet, and were built of pine timbers 1 foot square, with a solid stay across the center. At the bottom they were extended at right angles under the river to a distance of 50 and 100 feet on the United States and Canadian sides respectively. These horizontal shafts were 4 feet square and were built of the same material and in the same manner as the vertical ones. These tests were completed about the middle of the year 1887.

The nature of the strata to be excavated was first about two feet of sand of the common yellow kind, such as is found on the sea shore. Underlying this was what appeared to be a mixture of quicksand and blue clay. This extended to a depth averaging about 12 feet, and under this lay a strata of adhesive blue clay, which increased in tenacity as the depth increased. This clay was found to be of a shifting nature, and great care was necessary in building, as the small spaces outside the wooden shaft were rapidly filled, and gave this great mass of blue clay a chance to move, when a general sinking of the ground at the top for several feet around could be noticed.

About the middle of the year following, the permanent work of the brick shafts commenced. These shafts are 23 feet in diameter and are 2 feet 6 inches in thickness, which gives them an outside diameter of 28 feet. They are built directly over the test shafts. It was intended to build these shafts on cast iron shoes with a knife edge (as shown in the engraving), and to excavate below and build on above at the same time, and allow the whole mass of brickwork to sink with its own weight into the hole prepared for it. This answered very well for the first 30 feet, when the clay closed on the masonry, and so prevented its progress. Some dynamite bombs were exploded near the base. The shaft then sank about four inches more and then became a fixture. They were then obliged to brick up underneath and build downward, but this was not at all satisfactory, owing to the size of the shaft and the closing, shifting nature of the clay to be gone through. Each section of brickwork as it was added was separated from the one above by a crack or number of cracks varying from one-fourth of an inch to three inches. This was quite unavoidable, owing to the unstable foundation afforded by the clay. Less difficulty was experienced in sinking the Canadian shaft than the American one. The former was sunk to the required depth of 98 feet, but no sooner had it been accomplished than a general settling of ground around the top took place, which necessitated the removal of all the machinery, plant and stores some yards away to safe ground. Simultaneously with the sinking of the ground at the top of the shaft the soft blue clay was found to be rising in the bottom, evidently forced up by means of the increased pressure resultant of the vast settling. It was noticed at the same time that the shaft was losing its circular form. No doubt this was due to the great pressure. Fearing an entire collapse of the shaft, hasty means were at once taken, and large beams were placed across at different spots up and down the shaft; but this was soon seen to be of little use, as the beam supports showed an inclination to press holes in the structure as the sides still continued to close on one another. The shaft was then as quickly as possible filled with sand. This was done in hopes of saving it. It has since been decided to fill this shaft up permanently with clay taken from the tunnel, as it is now deemed unsafe.

Operations ceased on the United States shaft when it reached a depth of 53 feet, and it was decided to let it remain until reached by the subterranean portion on that side. When completed this shaft will be lined with cast iron similar to that of which the tunnel is constructed. The position of these shafts will be seen by reference to the annexed engraving. Operations on these shafts were suspended on September 29, 1888, and the machinery and all equipment was then moved inland about 1,800 feet on the American side and about 1,900 feet on the Canadian, and operations on the two great cuttings were commenced in the beginning of January, 1889. The American cutting was carried to a depth of 53 feet, with an incline just light enough to enable an engine to pull out the excavated soil. The soil here is composed of a layer of quicksand on the top, with an average depth of 14 feet, and underneath is a solid body of stiff blue clay, similar to that met with in the shaft. Owing to the depth of the quicksand at the top and the shifting nature of the clay, it was thought necessary to make the cutting very wide to prevent landslides. The cutting was accordingly made about 200 feet wide at the widest and deepest part. It resembles the impression which would appear in sand after the removal of a pear which had been half submerged. The Canadian cutting was carried to a depth of 58 feet, but was not so wide as the American, it being considered unnecessary, as the ground had a much firmer appearance and was without quicksand. The crust was from 4 to 6 feet deep and composed of loose earth. It was, however, soon found necessary to widen the cutting, as a large landslide occurred. Hundreds of tons of earth and clay slid down and filled the bottom of the cutting to a depth of about 16 feet, and threatened to spread to the foundations of the workshops standing on the top of the bank. To obviate this it was decided to fill up for a distance of about 50 feet and commence boring the tunnel further back.

The walls of the tunnel are constructed of cast iron segments, thirteen of which and a key form a circle. The diameters of the cast iron segments are: Length 4 ft. 10 inches, width 18 inches, thickness 2 inches, with flanges inside, 6 inches deep, and one and three-fourths of an inch in thickness. These segments are cast with 32 holes in them, viz., 12 in each side flange and 4 in each end. They are secured in their places with bolts ⅞ inch in diameter. The outside diameter of the tunnel is 21 feet, and 20 feet inside. The circle taken by the bolts in the flanges is 20 feet 5 inches.

The tunneling is being carried on by means of a pair of Beach hydraulic shields, one of which is employed in each heading. At this point a brief history of this device may not be uninteresting.

It is the invention of Mr. Alfred E. Beach, of the Scientific American, and was designed by him and tried in 1868 (patented 1869) for the purpose of excavat-

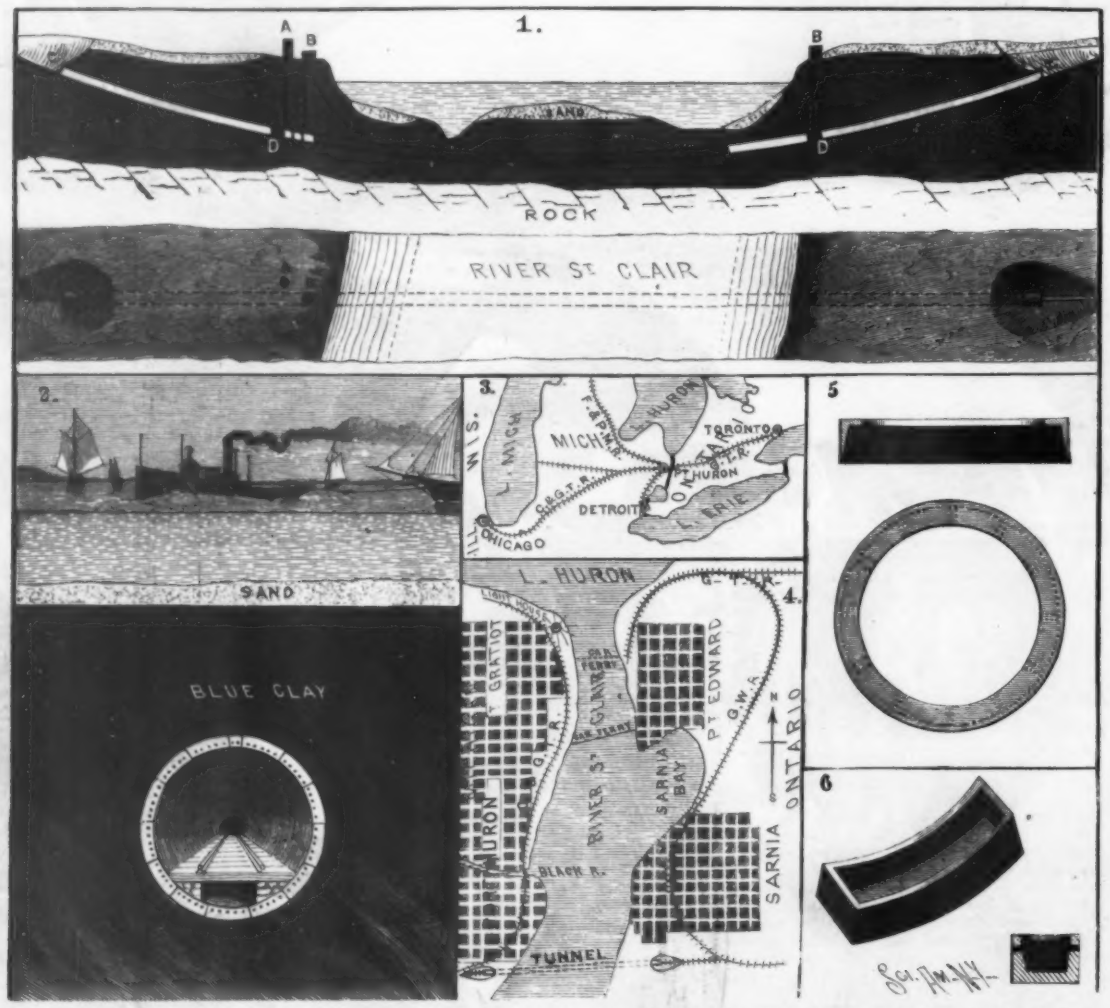


Fig. 1.—Sectional elevation and plan of tunnel; A, pump shaft, B, brick air shafts, C, cuttings, DD, bulkheads. Fig. 2.—Cross section of tunnel and river. Fig. 3.—Map showing location. Fig. 4.—Plan of Pt. Huron and Sarnia, showing position of tunnel. Fig. 5.—Section and plan of iron shoe of shaft. Fig. 6.—Segment of cast iron of which the tunnel is composed.

THE GREAT RAILWAY TUNNEL UNDER THE ST CLAIR RIVER, BETWEEN THE UNITED STATES AND CANADA.

ing under the streets of New York, with a view to an underground railway. At that early period the need of rapid city transit for passengers was strongly felt, but there was great opposition on the part of property owners along the line of the proposed railway, through fear that the buildings would be injured if a tunnel were carried on a lower level than the foundations; added to which would be serious loss of business by the closing and tearing up of the streets during the construction of the work. Mr. Beach determined to show the fallacy of both of these objections by excavating a short piece of tunnel under the most crowded part of Broadway, at a lower depth than the adjacent buildings, and without interrupting business or traffic. He accordingly constructed the hydraulic shield or underground boring machine, which he set to work, and with it constructed a tunnel extending under Broadway from Warren Street to Park Place, large enough to receive a small street railway car, the length of the tunnel being between three hundred and four hundred feet. This tunnel was 9 ft. 4 in. in exterior diameter. It was started at the head of Warren Street, from which it turned underground on a radius of about 50 ft. into Broadway. The curved portion of the tunnel was walled with cast iron plates, put up in segments and united by means of screw bolts; the straight portion was walled with brick masonry. The object of the shield was to protect the workmen while excavating the earth and building the tunnel.

The shield consists of a strong cylinder somewhat

resembling a huge barrel with both ends removed. The front end of the cylinder is sharpened, so as to have a cutting edge to enter the earth. The rear end of the cylinder, for a length of two feet or so, is made quite thin, and is called the hood. Arranged around the main walls of the cylinder and longitudinally therewith are a series of hydraulic jacks, all operated from a common pump, each jack having cocks, whereby it may be cut off from the pump whenever desired.

Within the shield are vertical and horizontal braces and shelves. When at work, the iron plates or the masonry, of which the tunnel is composed, are first built up within the thin hood of the shield, the hydraulic jacks are then made to press against the end of the tunnel plates or masonry, which has the effect to push the shield ahead into the earth for a distance equal to the length of the pistons of the jacks, say two feet, or not quite the length of the hood, and, as the shield advances, men employed in the front of the shield dig out and carry back the earth through the shield. By the advance of the shield, the hood, within which the iron or masonry tunnel is built, is drawn partly off from and ahead of the constructed tunnel, thus leaving the hood empty. The pistons of the hydraulic jacks are then shoved back into their cylinders, and a new section of tunnel is built up within the hood as before described. The shield is then pushed ahead, and so on. The extreme end of the tunnel is always within and covered and protected by the hood. In this manner the earth is rapidly excavated or bored out, and the tunnel built, without disturbing the surface of the ground.

The floor of the Broadway tunnel above mentioned was 21½ feet below the pavement. It was carried under sewers and beneath the Croton water mains. The work was executed while the street was thronged with omnibuses and heavy teams, and few persons, except those directly interested, had any knowledge that a tunnel was in progress until after it was completed. It was then opened to the public, and many thousands of people enjoyed the privilege of riding in the car, which was worked back and forth in the tunnel by the pneumatic or air pressure system.

By means of the system of hydraulic jacks capable of either combined or separate action, Mr. Beach was enabled to govern the direction of his tunneling shield with the utmost precision, making it to ascend or descend in the earth, according to grade required, or travel on a curve of any desired radius. The first machine attracted much attention on the part of engineers. It was illustrated and described in the SCIENTIFIC AMERICAN of March 5, 1870, also in the *Manufacturer and Builder* in 1872, and in various other publications.

Since the construction of the Broadway tunnel the Beach hydraulic shield has been employed on a number of important engineering works, with much success, and it is now generally recognized as an important adjunct in the execution of various classes of underground tunnels. At Buffalo it was used to carry a large sewer under a main street and under a canal. At Chicago it was used in the construction of one of the lake tunnels. In London, 1886-89, it was employed in the construction of the City and Southwark Subways, recently completed, and soon to be opened for public traffic as the underground electric railways. These two tunnels extend from the Monument, London, and pass under the Thames River, Great Dover Street, Kennington Park Road, and other thoroughfares to Clapham, a distance of about three miles. The exterior diameter of each of these tunnels is 11 ft. 6 in.

The Beach hydraulic shield has also been brought into use recently in the railway tunnels now in process of construction under the Hudson River, between New York and Jersey City, N. J. The shields here used have an external diameter of 19 ft. 11 in.

As before stated, the tunneling of the St. Clair River is being carried on by means of the Beach hydraulic shields which precede the diggers. Each shield is circular, 21 feet 7 inches in diameter, 16 feet long, and is built of plate steel, one inch thick. It is divided into twelve compartments by means of two horizontal and three vertical stays, which are built up to a thickness of two inches. These stays have a knife edge in front and extend back ten feet, leaving six feet of clear cylinder into which the end of the tunnel extends. Ten of the compartments are permanently closed and brazings of angle iron placed across them. The other two are provided with heavy iron doors which can be closed at once in case of accident or danger. These doors are situated at the bottom in the center, and through them is passed all the excavated matter. Flush with this heading (with their cylinders extending forward into the compartments) are twenty-four hydraulic rams at equal distances around the shield. These rams are eight inches in diameter and have a stroke of 24 inches. By their means the shield is forced forward enough to admit of another section of castings, viz., 18 inches. Each of these rams can be worked separately, as may be seen by the sketch of the back view of the shield. The power is supplied by a Worthington pump which is capable of producing a pressure of 5,000 pounds per square inch, which will amount to 125 tons per ram, or 3,000 tons on the 24 rams. The greatest pressure as yet used is 1,700 pounds per square inch, which is 40 tons per ram and 1,000 tons on the shield.

These shields weigh eighty tons each, and were built by the Tool Manufacturing Company, of Hamilton, Canada. They were brought to their destination in pieces, and erected at the tops of the great cuttings, on the north side in both cases, at which side are also the machines and workshops which have been erected. This immense machine when completed was rolled down the side of the cutting on a wooden track composed of four rails of wood, each one foot square and placed about four feet apart. It was restrained in its downward course by means of six large ropes which were passed around it, fixed at one end to the upper end on the wooden track and coiled around piles, with a number of men to lower out when the order was given. From the time at which the machine first moved to the time it was resting on the cradle of wood (which was prepared for it) at the bottom was only one hour and twenty minutes. A better idea can be obtained by referring to the annexed engraving, which is taken from a photograph, and which shows them in the act of lowering the shield on the Canadian side. When in position a backing of timbers one foot square was erected against the dead clay, and to this backing the first section of the tunnel was bolted, and others were added by means of the derrick which is shown in the engraving of the cutting on the American side. A similar backing was used on the Canadian side, with the exception that, instead of having a solid back of clay as a support, it had a number of shores.

The erection of the castings is accomplished by means of a circular crane which revolves on a spindle in the center of the shield (see sketch of back view of shield), and is provided with a vise at one end, with which to grip the casting, and a counterbalance weight at the other. When a casting has been made secure, the arm of the crane rises about nine inches, thereby shortening the vise arm, and lengthening the counterbalance arm. This gives the cast iron segment a clearance to travel around to the desired point, where it can be placed in position, by reversing the sliding motion.

The machinery plant necessary for this great undertaking is as follows: One boiler house, containing three boilers, two of which are kept in steam at a time; one machine shop, containing a planing machine, a drilling machine, and bolt-screwing machine. The planing machine is provided with an extra bed at each end, distant from the working bed about two feet. It is also supplied with an extra table. By this means the plane is kept almost incessantly at work, as while one table load is being planed, the other table is being loaded again, and unloaded when one lot is finished. The table is run on to one of the extra beds, and the newly laden table on the other bed is placed on the plane. There is one carpenter's shop, one smith shop, an electric light room containing two dynamos and engines, a room containing blower engine and blower, a hoisting engine in another apartment, and a pump in the pit to pump out loose water. This plant is precisely similar on both sides of the river.

The tunnel when completed will be 6,050 ft. in length from cutting to cutting, and is divided as follows: From the American cutting to the river edge 1,800 ft., from the Canadian cutting to the river edge 1,950 ft., and distance across the St. Clair River 2,300. Of this 6,050 ft., 4,150 ft. has already been constructed, viz., 2,215 ft. on the American side and 1,740 on the Canadian.

In crossing the river the greatest danger and difficulty will be experienced in the excavation and construction underneath the deep channel in the river. At this point the thickness of clay between the top of the tunnel and the bed of the river is only 12 ft. This channel is near the Canadian side, as may be seen by reference to the engraving. A compressed air plant has lately been added to the list of machinery, and has been placed close to the brick shafts on the river banks. The plant is precisely the same on both sides. Work is now being carried on on both sides under compressed air. The pressure on the American side commenced with 10 pounds to the square inch, but has since been raised to 16 pounds per square inch. The compressed air was not used on the Canadian side for some weeks after it had been in operation on the American. The pressure there commenced and is still at 18 pounds per square inch. A bulkhead of solid brick and cement has been built in the tunnel close to the water's edge. It is six feet in thickness and is arranged with airtight doors on either side, so forming a lock through which the small cars pass with the excavated matter. It was thought at first that progress would be much more slow under compressed air, but this is not so. The work progresses just as fast as before. The amount constructed varies from 3 ft. to 16 ft. per day of 24 hours, except in cases of delay from breakdowns and such like.

The tunnel proper was commenced in August of 1889, and the expedition with which it has been completed so far (for its manner of construction renders it complete as the shield proceeds) has beaten all previous records of tunnel construction, and has so far proved a success beyond expectations, inasmuch as it shows a fewer number of accidents than other types of tunnel, the most serious accident up to date being a broken leg. The idea of building this tunnel of cast iron segments originated with Mr. Joseph Hobson, of Hamilton, Ontario, who is chief engineer of the St. Clair Tunnel Co. and is also chief engineer of the Great Western division of the G. T. R. of Canada. The fact that no less than 4,150 ft. out of the 6,050 has been constructed speaks volumes for Mr. Hobson's skill in tunnel construction. At a meeting of directors a short time since, Sir Joseph Hickson is reported to have expressed his belief that the tunnel would be completed for traffic within eighteen months. Mr. Thomas Murphy, of New York, who is superintendent of excavation, is thoroughly sanguine about its healthy state. Mr. Murphy is a man well versed in these matters, and is thoroughly competent, having been connected with the construction of several tunnels of note throughout the United States.

The tunnel will drain itself into the pump shaft, A, Fig. 1, on the Canadian side. This shaft is 18 ft. in diameter and 113 ft. in depth, being carried to the rock which lies at that depth.

The cost of this tunnel was estimated at $3,000,000, but it is now thought that (notwithstanding the immense amount of money expended on the test and brick shafts) that it will not reach that figure. Should another tunnel be put through, which we shall not be at all surprised to see in the near future, we shall have a much fairer chance to compare the certain and marked advantages which the cast iron tunnel possesses over the old style brick and cement tunnels.

The tunnel proper is 6,050 ft. in length and 21 ft. outside diameter, the Beach hydraulic shield being 21' 6" in diameter. The amount of soil excavated for this portion of the work amounts to 2,196,400 cubic ft. and will require 55 962,300 pounds of cast iron lining, secured together with 859,242 bolts, ¾" in diameter. The success attained by Mr. Hobson in the face of so many obstacles and the difficult nature of the soil to be gone through indicates his complete mastery of the subject and reflects high credit upon his skill as an engineer. The tunnel construction furnishes employment to 700 hands.

REFERENCES TO THE ENGRAVING ON FIRST PAGE.

Fig. 1.—Rear view of the Beach hydraulic shield, showing the hood within which the tunnel is built and the heads of 24 hydraulic rams by which the shield is pushed ahead. Also showing the swinging crane for placing the cast iron segments.

Fig. 2.—The shield in place, on grade, and ready to enter the heading. The cutting edges of the shield are seen in front. At the rear of shield is seen a portion of the constructed iron tunnel pushed up against the temporary timber backing.

Fig. 3.—Interior view showing the Beach hydraulic shield as worked in the heading. The cast iron segments composing the tunnel are built up within the thin rear part or hood of the tunnel. The hydraulic rams are then made to press against the end of the tunnel, as shown, which forces the shield ahead and leaves the constructed tunnel behind in the earth. The swinging crane assists in placing the cast iron segments. As the shield advances, the men in the front part dig and throw back the earth.

Fig. 4.—The front of the shield, showing its cutting edges, its cross shelves and vertical supports.

Fig. 5.—The great shield as it appeared when being lowered by cables to its place at the heading.

THE SMELTING OF IRON.

THE annual general meeting of the Society of Chemical Industry was held recently at Nottingham, in the chemical lecture room at University College. After the formal business had been dispatched, the president, Sir Lowthian Bell, read an address entitled "The Smelting of Iron Ores Chemically Considered." In introducing the subject, he pointed out that a material like cast iron, the manufacture of which depended, apparently, on the most elementary principles, needed even more attention and research at the hands of the chemist than many products usually considered as definitely belonging to manufacturing chemistry, as, for example, soda ash, inasmuch as trifling percentages of impurity that might be industrially negligible in the latter became of extreme importance on account of their influence on the quality of the former. Such being admitted, he would freely advance the proposition that the work of the blast furnace ranked as one of the most interesting and successful applications of chemical science known in industrial enterprise. Taking first into consideration the *rationale* of the smelting process, his practical experience had led him to dissent from the theory usually advanced, and well described in such works as Roscoe and Schorlemmer's "Treatise on Chemistry," and maintain that reduction of the ore to metallic iron began at a lower temperature—150 deg. C.—than was commonly supposed, and that the importance of the function of the upper part of the column of ore in intercepting and eventually returning the heat that would otherwise be lost was underrated. Turning to the question of the quantity of carbon dioxide that might be expected to be present in the escaping gases, he fixed 5 97 cwt. of carbon as carbon dioxide per ton of iron made as the best that could be expected, a more perfect combustion of the carbon in a blast furnace being impracticable. Passing to the economy effected by the use of the hot blast, the president hinted that it was perhaps a matter for congratulation that Neilson, its inventor, lacked scientific knowledge, for the explanation of its efficacy was so obscure that professed scientists might well have been deterred from pursuing the subject. In this respect, as in many others, experience absolutely contradicted *a priori* views; it appeared plausible, for instance, that a more complete utilization of the available heat might be obtained by running a furnace with the hot blast slowly, so that the heat might be better imparted to the upper layers of ore, but the contrary was true. It was found that the hotter the blast is, the quicker the furnace can be driven, and the cooler are the escaping gases. Yet another illustration of a successful issue resulting from a somewhat blind following of instinct rather than scientific insight was furnished by the advantage gained by increasing the height of the blast furnace. John Vaughan first built a furnace 71 ft. in height, more with the view of increasing the output than effecting fuel economy, but incidentally achieved this as well. Nevertheless it was unwise to push this principle too far for an ironmaster of his—the president's—acquaintance, who built two colossal furnaces 100 ft. high, effected no saving in fuel, as, indeed, Sir Lowthian Bell had prophesied. All things considered, he was in favor of a furnace of more moderate dimensions, *e. g.*, 80 ft. in height, and with a capacity of 16,000 cubic ft.

Recent attempts had been made to increase the temperature of the blast, and thereby the economy of the fuel, and the air had been heated in "brick stoves" built on the Siemens regenerative system. In spite of such enterprise, and the somewhat sensational results, *e. g.*, 13 to 16 cwt. of average Durham coke per ton of iron talked of, Sir Lowthian Bell said that his own expectations were limited to about 20 cwt. Further effort had been made to save fuel by decarbonating the limestone necessary as a flux, previous to its employment in the blast furnace; and as raw coal was available for this purpose, a margin of economy existed; but in view of the tendency of caustic lime to become recarbonated before it reached the zone in which it was to serve as a flux, there was considerable doubt whether sober sense commended such a course. The general conclusions arrived at are best reproduced in Sir Lowthian Bell's own words: In answer to those who, in order to effect further economy in the consumption of coke in the blast furnace, recommend the use of furnaces of great height and large dimensions, who advocate the use of caustic lime, and insist on imparting unmanageable heat to the blast, I would beg attention to the lessons taught by the example given under column E—alluding to tables accompanying the paper. There, a furnace of 15,500 cubic ft. capacity, blown with air at a comparatively moderate temperature, and using raw limestone, compares favorably with furnaces twice its size with a much hotter blast and deriving such advantages as calcined limestone is regarded as capable of affording. I am very far from undervaluing the very great importance of the lessons taught by the various trials made with the view of reducing the cost of producing pig iron. There is no doubt the iron trade is under very great obligations to those who, at considerable expense and trouble to themselves, have given us the benefit of their experience, without which almost all speculation is useless.

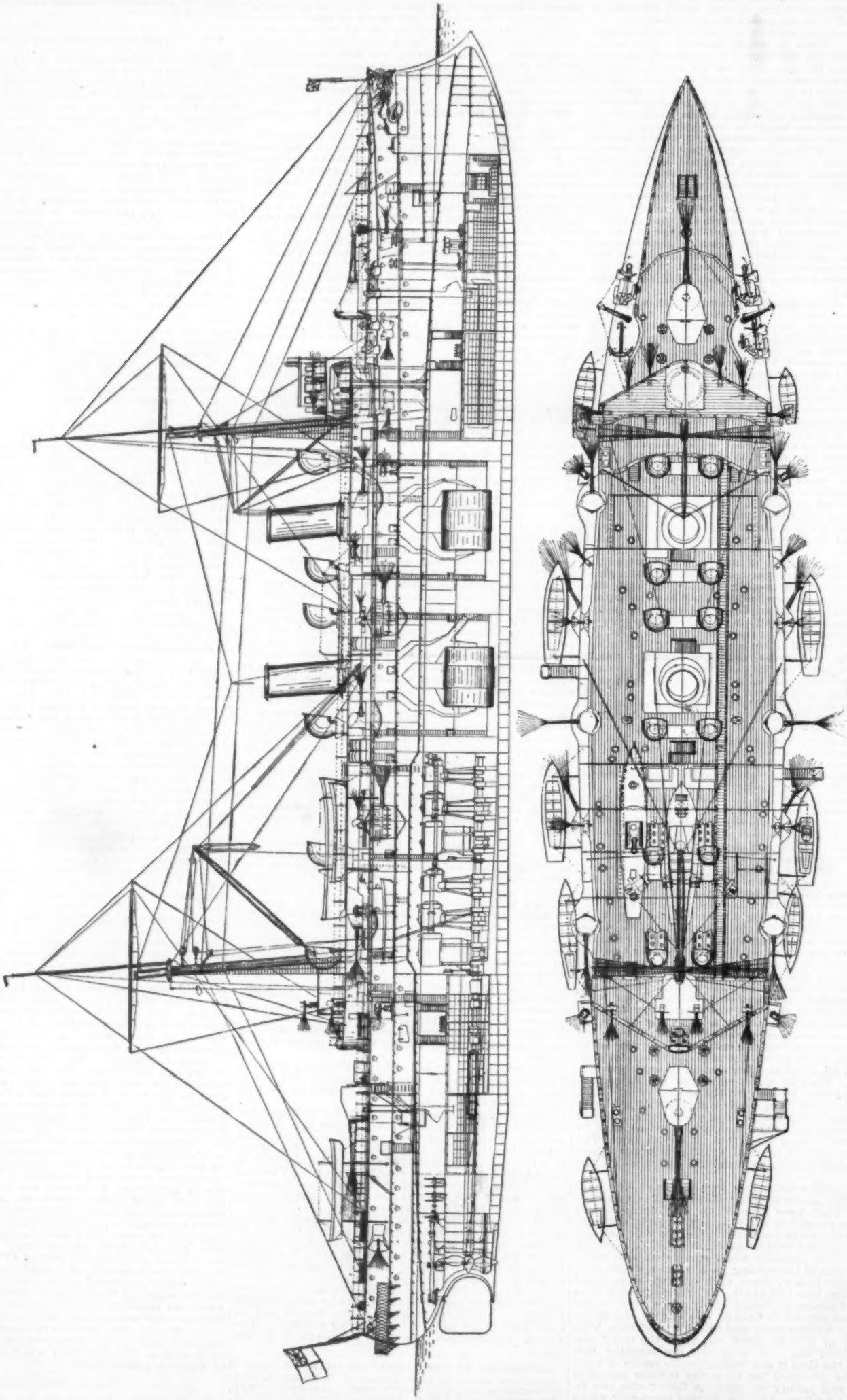
The paper concluded with an account of the experimental work on which these deductions are based, while the questions of the presence and quantity of cyanogen and ammonia in the blast furnace, the fume given off, and other matters of chiefly chemical interest, were dealt with, completing a masterly treatise on a subject bristling with difficulties, the presence of which is patent to all.

DR. CHAILLÉ, the well known statistician, states that the average life of women is longer than that of man, and in most parts of the United States woman's expectation of life is greater.

H. M. S. BLENHEIM.

ON July 7th was launched from the yard of the Thames Ironworks and Shipbuilding Company the Blenheim, intended to be the fastest ship in the English navy. She was designed by Mr. W. H. White, assistant controller and naval constructor, and is 375 ft. long between perpendiculars, 65 ft. beam amidships, and 38 ft. deep. Her draught of water is 25 ft. 6 in., and her displacement 9,000 tons. She is in many respects similar to the Warrior, which was launched from the dock yard of the same company thirty years ago. The Warrior has the same draught, is 5 ft. longer, but 7 ft. narrower, and her displacement is 8,827 tons. Her triple expansion engines, by Messrs. Humphrys, Tennant & Co., are to be 20,000 indicated horse power, as against 5,000 indicated horse power in the case of the Warrior. Her trial speed is to be 22 knots, as against the 14 knots of the earlier vessel, and her average speed 18¼ knots in smooth water.

The armor of the Blenheim, weighing 1,190 tons, is principally concentrated upon the protective deck. The hull is constructed of steel upon the usual cellular system. The hold space is subdivided minutely by watertight bulkheads and decks; there is a cellular double bottom. The inner protective deck consists of a roof of curved steel covering the hold from stem to stern, the eaves of the roof, so to speak, being 6½ ft. below, while the top rises 1½ ft. above, the waterline. This sharply curving deck is 6 in. thick over the machinery and



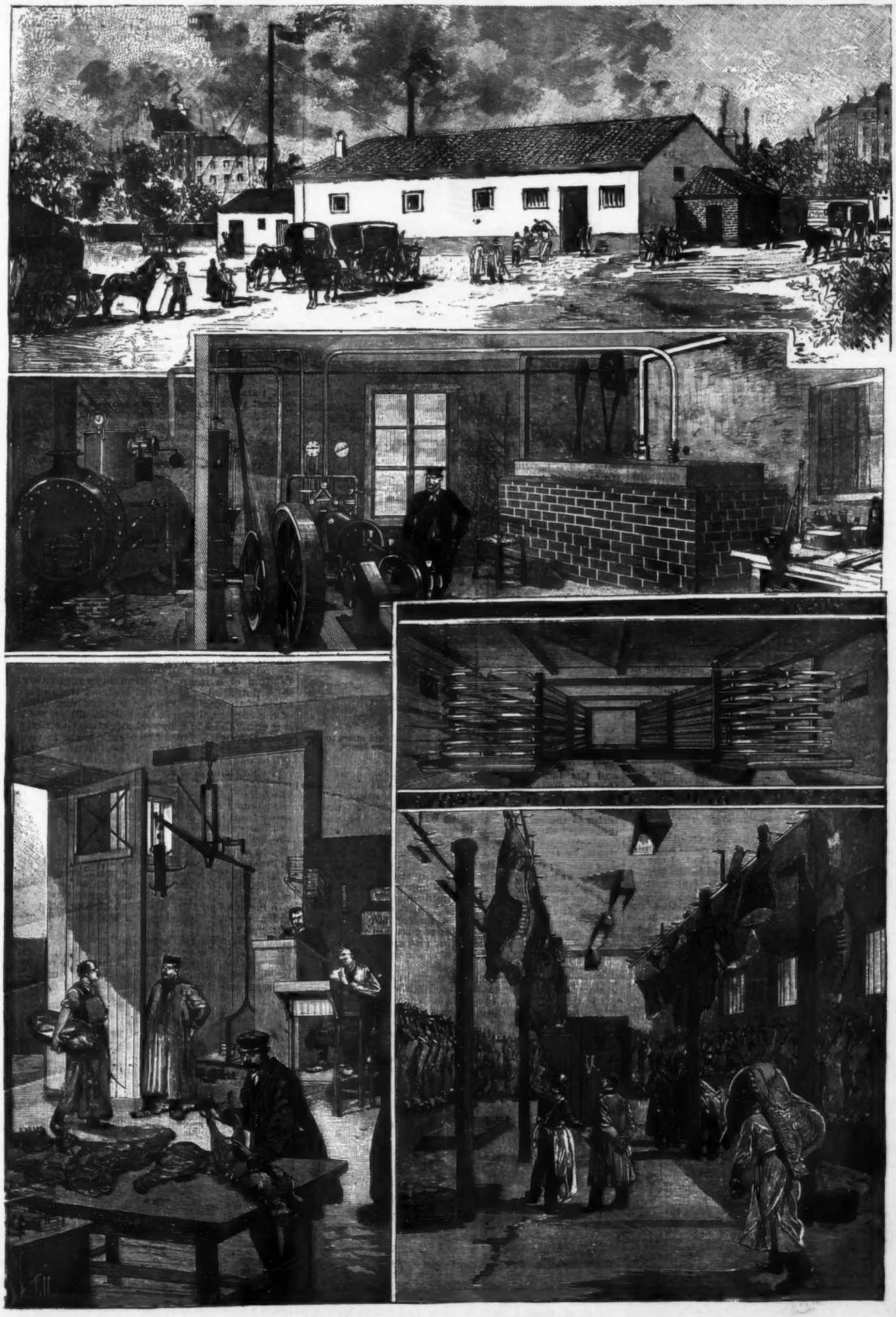
H. M. S. BLENHEIM.

engines, and 3 in. thick elsewhere. The vitals of the ship—the propelling apparatus, steering gear, magazine, and shell rooms—will all be beneath its protection. There is no side armor of any kind. She will carry two 24 ton and ten 5 ton breech-loading guns, sixteen 3 pounder quick-firing guns, one 1 in. and six 0·45 in. Nordenfelts. Of these guns, six are to be carried on the upper deck—two for use ahead and on the broadside, two for use astern and on the broadside, and two amidships—training from 60 deg. before to 60 deg. abaft the beam. The remaining four are to be carried on the main deck, two on each broadside, in casemates composed of 6 in. steel-faced armor. It appears her offensive powers are completed by a bow strengthened for ramming.—*The Engineer*.

A COLD STORAGE ESTABLISHMENT.

WE give herewith some illustrations of an establishment for the cold storage of meat, very recently inaugurated at Paris, on Flandre Street, in the immediate vicinity of the abattoirs, and due to the initiative of Mr. V. Velly, one of the largest wholesale butchers in the city.

We shall not describe the operation of such an establishment, but shall merely recall the principal services that cold storage *entrepots* are capable of rendering. To the butchering business, they assure of the almost indefinite preservation of its products, and they allow consumers to procure, at all seasons, and in the hottest



PRESERVATION OF FOODS BY COLD—INSTALLATION OF A REFRIGERATING DÉPOT ON THE RAOUL PICTET SYSTEM.
1. Exterior view of the establishment. 2. The boiler. 3. The machine room. 4. Refrigerating chamber. 5. Salesroom. 6. Receiving office.

weather, meat that is always absolutely wholesome and of which all the nutritive and succulent properties that the finest gourmet could desire are preserved by a stay in a temperature varying from 2° to 4° above zero. In current practice, Mr. Velly's *entrepot* does not freeze the meat, but merely keeps it at a low temperature. It is designed to preserve 44,000 pounds of meat—a mouthful for Paris.

At this moment, when the provisioning of the capital and the large strongholds of France forms the subject of very profound studies, at the Ministry of War, as well as in the city services, we shall be able, in this private enterprise, to find some valuable practical instruction, that will permit of proceeding with certainty in this new direction—new for France, at least; for the Industrial Company of the Raoul Pictet Processes, a society essentially French, to which was confided the Velly installation, has already established a large number in foreign countries, especially at Geneva, Caronge, Vevay, Montreux, etc., where all are operating to the entire satisfaction of the public and the butchery business, thus justifying the dictum, which is also too true, that progress made in France is much more quickly taken advantage of by foreigners than by ourselves.—*L'Illustration.*

PROBLEMS IN THE PHYSICS OF AN ELECTRIC LAMP.*

MORE than eighty years ago Sir Humphry Davy provided the terminal wires of his great battery of 2,000 pairs of plates with rods of carbon, and, bringing their extremities in contact, obtained for the first time a brilliant display of the electric arc.† The years that have fled away since that time have seen all the marvelous developments of electro-magnetic engineering, have placed in our possession the electric glow lamp, and brought the art of electrical illumination to a condition in which it progresses each year with giant strides. In addition to the importance attaching to their ever-increasing industrial use, there are many questions of purely scientific interest which present themselves to our minds when we proceed to examine the actions that take place when a carbon conductor is rendered incandescent in a high vacuum, or when an electric arc is formed between two carbon poles. It is to a very few of these physical problems that I desire to direct your attention to-night, but more especially to one which is particularly interesting from the bearing which it has on the general nature of electric discharge.

We know as a very familiar fact that if we attempt to raise the temperature of a carbon conductor inclosed in a vacuum beyond a certain limit, not far removed from the melting point of platinum, the carbon begins to volatilize with great rapidity. If an electric glow lamp has passed through its carbon more than a certain strength of current, the glass bulb speedily becomes darkened by a deposit of this volatilized carbon condensed upon it; and experience shows us that we cannot raise the temperature of that carbon beyond a definite point without causing this waste of the conductor to become very rapid. In the highly rarefied atmosphere within the bulb of a glow lamp, the carbon, when at its normal incandescence, must be considered to be projecting off molecules of carbon in all directions, partly in virtue of purely thermal actions, but probably also in consequence of certain electrical effects to be presently discussed. This scattering of the material of the carbon conductor takes place with disadvantageous rapidity from an industrial point of view at and beyond a certain temperature,‡ but it exists as well at much lower temperatures than that which is found to determine the practical limit of durability. A curious appearance is found in many incandescent lamps which have been "over-run," which shows us that this projection of carbon molecules from the hot conductor is not, perhaps, best described by calling it a vaporization of its substance, but that the surface molecules are shot off in straight lines, and that they reach the glass envelope without being hindered to any great extent by the molecules of the residual air.

If an electric current is passed through an otherwise uniform carbon conductor, which possesses at any one place a specific resistance higher than that of the remaining portion, the current, in accordance with a well known law, there develops a higher temperature, and the molecular scattering at that spot may in consequence be greatly exaggerated. It may be that the detrition of the conductor at that locality will be so great as to cut it through after a very short time. When the carbon has the form of a simple horseshoe loop, and when this molecular scattering takes place from some point in the middle of one branch, the molecular projection makes itself evident by producing a "molecular shadow" of the other leg upon the interior of the glass. I will project upon the screen an image of the carbon horseshoe loop taken from an old glow lamp, and you will be able to see that the filament has been cut through at one place. At that position some minute congenital defect caused the carbon to have a higher resistance, the temperature at that point when it was in use became excessive, and an intensified molecular scattering took place from that locality. On examining the glass bulb from which it was taken, we find that the glass has been everywhere darkened by a deposit of the scattered carbon except along one narrow line (see Fig. 1), and that line is in the plane of the carbon loop and on the side opposite to the point of rupture of the filament.§

I may illustrate to you, by a very simple experiment, the way in which that "shadow" has been formed. Here is a ∩-shaped rod: this shall represent the carbon conductor in the lamp; this sheet of cardboard placed behind it, the side of the glass receiver. I have affixed a little spray producer to one side of the loop, and from that point blow out a spray of inky water. Consider the ink spray to represent the carbon atoms shot off from the overheated spot. We see that the cardboard

FIG. 1.—Glow lamp, having the glass bulb blackened by deposit of carbon, showing the molecular scattering which has taken place from the point, a, on the filament, and the shadow or line of no deposit produced at b.

is bespattered on all points except along one line where it is sheltered by the opposite side of the loop. We have thus produced a "spray shadow" on the board (Fig. 2). The existence of these molecular shadows in incandescent lamps leads us therefore to recognize that the carbon atoms must be shot off in straight lines, or else obviously no such sharp shadow could thus be formed. This phenomenon confirms in a very beautiful manner the deductions of the kinetic theory of gases. I may remind you that at the ordinary temperature and pressure the mean free path of a molecule of air is deduced to be about four one-millionths of an inch. This is the average distance which such a gaseous molecule moves over before meeting with a collision against a neighbor which changes the direction of its path. Let the air be rarefied, as in these bulbs, to something like a millionth of the ordinary atmospheric pressure, and the mean free path is increased to several inches. The space within the bulb—though from one point of view densely populated with molecules of residual air—is yet, as a fact, in such a condition of rarefaction that a carbon molecule projected from the conductor can move over a distance of three or four inches on an average without meeting with interference by collision with another molecule,

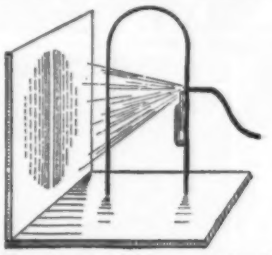


FIG. 2.—"Spray shadow" of a rod thrown on cardboard screen to illustrate formation of "molecular shadow" in glow lamps.

and the facts revealed to us by these shadows show that this must be the case. I have also at hand some Edison lamps in which these "molecular shadows" are finely shown, but in these cases the deposit on the interior of the bulb is not carbon but copper, because the molecular scattering has here taken place by excessive temperature developed at the copper clamps by which the carbon filament is attached to the platinum wires. The theory, however, is the same. The deposit of copper shows a fine green color by transmitted light in the thinner portions. One curious lamp also before me had by an accident an aluminum plate volatilized within the bulb. The glass receiver has in consequence been covered with a mirror-like deposit of aluminum, which on the thinner portions shows a fine blue color by transmitted light, and a silvery luster by reflected light. This lamp also shows a fine "molecular shadow."

These facts prepare us to accept the view that when a glow lamp is in operation the highly rarefied residual air in the interior of the bulb is being traversed in all directions by multitudinous carbon atoms projected off from the incandescent carbon conductor. I now wish to pass in review before you some facts which indicate that these carbon atoms carry with them electric charges, and that they are charged, if at all, with

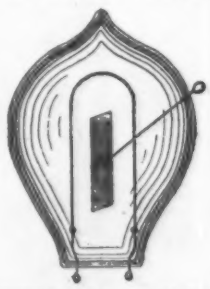


FIG. 3.—Glow lamp having insulated metal middle plate, M, sealed into bulb to exhibit "Edison effect."

negative electricity. I may preface all by saying that much of what I have to show you will be seen to be closely related to the phenomena studied by Mr. Crookes in his splendid and classical researches on radiant matter. Our starting point for this purpose is a discovery made by Mr. Edison in 1884, and which received careful examination at the hands of Mr. Preece in the following year,* and by myself more recently. Here is the initial experiment. A glow lamp having the usual horseshoe-shaped carbon (see Fig. 3) has a metal plate held on a platinum wire sealed through the glass bulb. This plate is so fixed that it stands up between the two sides of the carbon arch without touching either of them. We shall illuminate the lamp by a continuous current of electricity, and for brevity's sake speak of that half of the loop of carbon on the side by which the current enters it as the positive leg, and the other half of the loop as the negative leg. The diagram in Fig. 4 shows the position of the

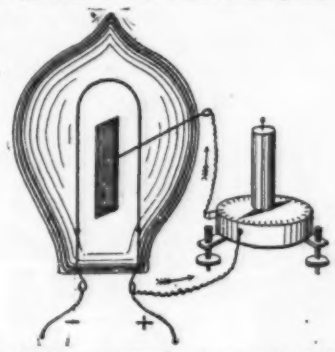


FIG. 4.—Sensitive galvanometer connected between the middle plate and positive electrode of a glow lamp, showing current flowing through it when the lamp is in action ("Edison effect").

plate with respect to the carbon loop. There is a distance of half an inch, or in some cases many inches, between either leg of the carbon and this middle plate. Setting the lamp in action, I connect a sensitive galvanometer between the middle plate and the *negative terminal* of the lamp, and you see that there is no current passing through the instrument. If, however, I connect the terminals of my galvanometer to the middle plate and to the *positive electrode* of the lamp, we find a current of some milliamperes is passing through it. The diagrams in Fig. 5 show the mode of connec-

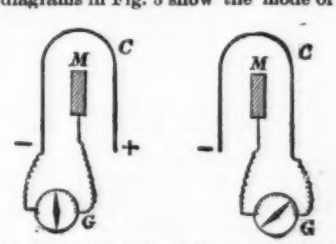


FIG. 5.—Mode of connection of galvanometer, G, to middle plate, M, and carbon horseshoe-shaped conductor, C, in the experiment of the "Edison effect."

tion of the galvanometer in the two cases. This effect, which is often spoken of as the "Edison effect," clearly indicates that an insulated plate so placed in the vacuum of a lamp in action is brought down to the same potential or electrical state as the negative electrode of the carbon loop. On examining the direction of the current through the galvanometer, we find that it is equivalent to a flow of negative electricity taking place through it *from* the middle plate *to* the positive electrode of the lamp. A consideration of this fact shows us that there must be some way by which negative electricity gets across the vacuous space from the negative leg of the carbon to the metal plate, while at the same time a negative charge cannot pass from the metal plate across to the positive leg. Before I pass away from this initial experiment, I should like to call your attention to a curious effect at the moment when the lamp is extinguished. Connecting the galvanometer, as at first, between the middle plate and the negative electrode of the lamp, we notice that though made highly sensitive, the galvanometer indicates no current flowing through it while the lamp is in action. Switching off the current from the lamp produces, as you see, a violent kick or deflection of the galvanometer, indicating a sudden rush of current through it.

In endeavoring to ascertain further facts about this effect one of the experiments which early suggested itself was one directed to determine the relative effects of different portions of the carbon conductor. Here is a lamp (see Fig. 6) in which one leg of the carbon

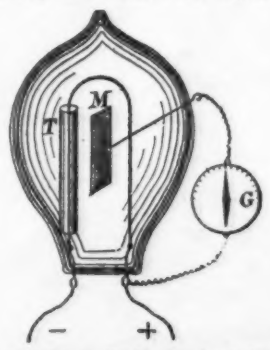


FIG. 6.—Glow lamp having negative leg of carbon inclosed in glass tube, T, the "Edison effect" thereby being annuled or greatly diminished.

horseshoe has been inclosed in a glass tube of the size of a quill, which shuts in one-half of the carbon. The bulb contains, as before, an insulated middle plate. If we pass the actuating current through this lamp in such a direction that the covered or sheathed leg is the

* Friday evening discourse delivered at the Royal Institution by Prof. J. A. Fleming, M.A., D.Sc., on February 14, 1890.—*Nature.*

† Sir Humphry Davy laid a request before the managers of the Royal Institution on July 11, 1808, that they would set on foot a subscription for the purchase of a large galvanic battery. The result of this suggestion was that a galvanic battery of 2,000 pairs of copper and zinc plates was set up in the Royal Institution, and one of the earliest experiments performed with it was the production of the electric arc between carbon poles, on a large scale. It is probable, however, that Davy had produced the light on a small scale some six years before, and, according to Quetelet, Cariet observed the arc between carbon points in 1803. See Dr. Paris's "Life of Sir H. Davy."

‡ When the rate of expenditure of energy in the carbon conductor is raised until it reaches a value of about 500 watts, or 360 foot pounds per second per square inch of radiative surface, a limit of useful temperature has been reached for economical working, under the usual present conditions of steam engine driven dynamos and modern glow lamps.

§ The writer desires to express his indebtedness to the editor of the *Electrician* for the loan of the blocks illustrating this abstract.

* Mr. Preece's interesting paper on this subject is published in the "Proceedings" of the Royal Society for 1885, p. 219. See also the *Electrician*, April 4, 1885, p. 436.

positive leg, we find the effect existing as before. A galvanometer connected between the plate and positive terminal of the lamp yields a strong current, while if connected between the negative terminal and the middle plate there is no current at all. Let us, however, reverse the current through the lamp so that the shielded or inclosed leg is now the negative one, and the galvanometer is able to detect no current, whether connected in one way or the other. We establish, therefore, the conclusion that it is the negative leg of the carbon loop which is the active agent in the production of this "Edison effect," and that if it is inclosed in a tube of either glass or metal, no current is found flowing in a galvanometer connected between the positive terminal of the lamp and this middle collecting plate.

Another experiment which confirms this view is as follows: This lamp (see Fig. 7) has a middle plate,

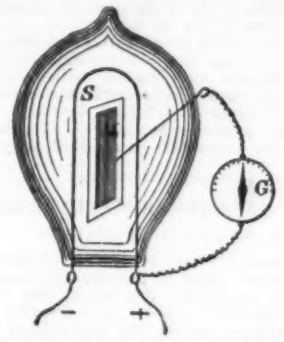


FIG. 7.—Glow lamp having mica shield, S, interposable between middle plate, M, and negative leg of carbon, thereby diminishing the "Edison effect."

which is provided with a little mica flap or shutter on one side of it. When the lamp is held upright, the mica shield falls over and covers one side of the plate, but when it is held in a horizontal position, the mica shield falls away from the front of the plate and exposes it. Using this lamp as before, we find that when the positive leg of the carbon loop is opposite to the shielded face of the plate, we get the "Edison effect" as before in any position of the lamp. Reversing the lamp current and making the same leg the *negative* one, we find that when the lamp is so held the metal plate is shielded by the interposition of the mica, and the galvanometer current is very much less than when the shield is shaken on one side and the plate exposed fully to the negative leg.

At this stage it will perhaps be most convenient to outline briefly the beginnings of a theory proposed to reconcile these facts, and leave you to judge how far the subsequent experiments confirm this hypothesis. The theory very briefly is as follows: From all parts of the incandescent carbon loop, but chiefly from the negative leg, carbon molecules are being projected which carry with them, or are charged with, negative electricity. I will in a few moments make a suggestion to you which may point to a possible hypothesis on the manner in which the molecules acquire this negative charge. Supposing this, however, to be the case, and that the bulb is filled with these negatively charged molecules, what would be the result of introducing into their midst a conductor such as this middle metal plate which is charged positively? Obviously, they would all be attracted to it and discharge against it. Suppose the positive charge of this conductor to be continually renewed, and the negatively charged molecules continually supplied, which conditions can be obtained by connecting the middle plate to the positive electrode of the lamp, the obvious result will be to produce a current of electricity flowing through the wire or galvanometer by means of which this middle plate is connected to the positive electrode of the lamp. If, however, the middle plate is connected to the negative electrode of the lamp, the negatively charged molecules can give up no charge to it, and produce no current in the interpolated galvanometer. We see that on this assumption the effect must necessarily be diminished by any arrangement which prevents these negatively charged molecules from being shot off the negative leg or from striking against the middle plate. Another obvious corollary from this theory is that the "Edison effect" should be annihilated if the metal collecting plate is placed at a distance from the negative leg much greater than the mean free path of the molecules.

Here are some experiments which confirm this deduction. In this bulb (Fig. 8) the metal collecting plate,

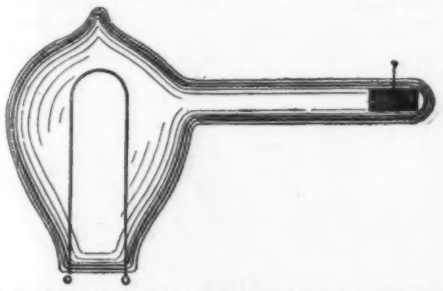


FIG. 8.—Collecting plate placed at end of a tube, 18 in. in length, opening out of the bulb.

which is to be connected through the galvanometer with the positive terminal of the lamp, is placed at the end of a long tube opening out of and forming part of the bulb. We find the "Edison effect" is entirely absent, and that the galvanometer current is zero. We have, as it were, placed our target at such a distance that the longest range molecule bullets cannot hit it, or, at least, but very few of them do so. Here, again, is a lamp in which the plate is placed at the extremity of a tube opening out of the bulb, but bent at right angles (Fig. 9). We find in this case, as first discovered by Mr. Preece, that there is no "Edison effect." Our molecular marksman cannot shoot round a corner. None of the negatively charged molecules can reach the plate, although that plate is placed at a distance not greater than would suffice to produce the effect if the bend were straightened out. Following out our hypothesis into its consequences would lead us

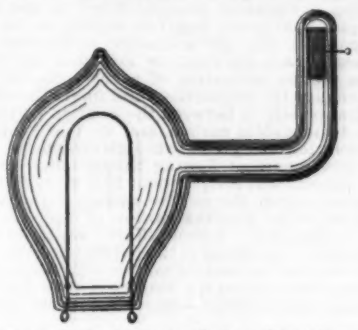


FIG. 9.—Collecting plate placed at end of an elbow tube opening out of the bulb.

to conclude that the material of which the plate is made is without influence on the result, and this is found to be the case. Many of the foregoing facts were established by Mr. Preece as far back as 1885, and I have myself abundantly confirmed his results.

We should expect also to find that the larger we make our plate, and the nearer that we bring it to the negative leg of the carbon, the greater will be the current produced in a circuit connecting this plate to the positive terminal of the lamp. I have before me a lamp with a large plate placed very near the negative leg of the carbon of a lamp, and we find that we can collect enough current from these molecular charges to work a telegraph relay and ring an electric bell. The current which is now working this relay is made up of the charges collected by the plate from the negatively charged carbon molecules which are projected against it from the negative leg across the highly perfect vacuum. I have tried experiments with lamps in which the collecting plate is placed in all kinds of positions, and has various forms, some of which are here, and are represented in the diagrams before you; but the results may all be summed up by saying that the greatest effects are produced when the collecting plate is as near as possible to the base of the negative end of the loops, and, as far as possible, incloses, without touching, the carbon conductor. Time will not permit me to make more than a passing reference to the fact that the magnitude of the current flowing through the galvanometer when connected between the middle plate and the positive terminal of the lamp often "jumps" from a low to a high value, or *vice versa*, in a remarkable manner, and that this sudden change in the current can be produced by bringing strong magnets near the outside of the bulb.

Let us now follow out into some some other consequences this hypothesis that the interior of the bulb of a glow lamp when in action is populated by flying crowds of carbon atoms all carrying a negative charge of electricity. Suppose we connect our middle collecting plate with some external reservoir of electric energy, such as a Leyden jar, or with a condenser equivalent in capacity to many hundreds of Leyden jars, and let the side of the condenser which is charged positively be first placed in connection through a galvanometer with the middle plate (see Fig. 10), while

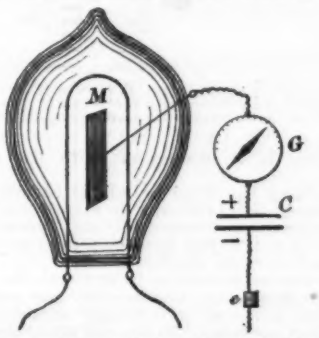


FIG. 10.—Charged condenser, C, discharged by middle plate, M, when the positively charged side of condenser is in connection with the plate and other side to earth, *e*.

the negative side is placed in connection with the earth. Here is a condenser of two microfarads capacity so charged and connected. Note what happens when I complete the circuit and illuminate the lamp by passing the current through its filament. The condenser is at once discharged. If, however, we repeat the same experiment with the sole difference that the negatively charged side of the condenser is in connection with the middle plate, then there is no discharge. The experimental results may be regarded from another point of view. In order that the condenser may be discharged as in the first case, it is essential that the negatively charged side of the condenser shall be in connection with some part of the circuit of the incandescent carbon loop. This experiment with the condenser discharged by the lamp may be then looked upon as an arrangement in which the plates of a charged condenser are connected respectively to an incandescent carbon loop and to a cool metal plate, both being inclosed in a highly vacuous space, and it appears that when the incandescent conductor is the negative electrode of this arrangement, the discharge takes place, but not when the cooler metal plate is the negative electrode of the charged condenser. The negative charge of the condenser can be carried across the vacuous space from the hot carbon to the colder metal plate, but not in the reverse direction.

This experimental result led me to examine the condition of the vacuous space between the middle metal plate and the negative leg of the carbon loop in the case of the lamp employed in our first experiment. Let us return for a moment to that lamp. I join the galvanometer between the middle plate and the negative terminal of the lamp, and find, as before, no indication of a current. The metal plate and the negative terminal of the lamp are at the same electrical potential. In the circuit of the galvanometer we will insert a single galvanic cell having an electromotive force of rather over one volt. In the first place let that cell be so inserted that its negative pole is in connection with the middle plate, and its positive pole in connection through the galvanometer with the negative terminal of the lamp (see Fig. 11). Regarding the circuit of

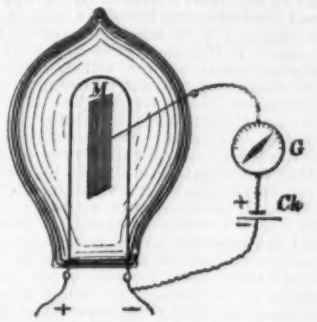


FIG. 11.—Current from Clark cell, *Ck*, being sent across vacuous space between negative leg of carbon and middle plate, M. Positive pole of cell in connection with plate, M, through galvanometer, G.

that cell alone, we find that it consists of the cell itself, the galvanometer wire, and that half inch of highly vacuous space between the hot carbon conductor and the middle plate. In that circuit the cell cannot send any sensible current at all, as it is at the present moment connected up. But if we reverse the direction of the cell so that its positive pole is in connection with the middle plate, the galvanometer at once gives indications of a very sensible current. This highly vacuous space, lying between the middle metal plate on the one hand and the incandescent carbon on the other, possesses a kind of unilateral conductivity, in that it will allow the current from a single galvanic cell to pass one way but not the other. It is a very old and familiar fact that in order to send a current from a battery through a highly rarefied gas by means of metal electrodes, the electromotive force of the battery must exceed a certain value. Here, however, we have indication that if the negative electrode by which that current seeks to enter the vacuous space is made incandescent, the current will pass at a very much lower electromotive force than if the electrode is not so heated.

A little consideration of the foregoing experiments led to the conclusion that in the original experiment, as devised by Mr. Edison, if we could by any means render the middle plate very hot, we should get a current flowing through a galvanometer when it is connected between the middle plate and the negative electrode of the carbon. This experiment can be tried in the manner now to be shown. Here is a bulb (Fig. 12) having in it two carbon loops; one of these is

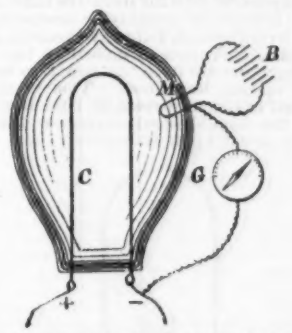


FIG. 12.—Experiment showing that when the "middle plate" is a carbon loop rendered incandescent by insulated battery, B_1, a current of negative electricity flows from M to the positive leg of main carbon, C, across the vacuum.

of ordinary size, and will be rendered incandescent by the current from the mains. The other loop is very small, and will be heated by a well insulated secondary battery. This smaller incandescent loop shall be employed just as if it were a middle metal plate. It is, in fact, simply an incandescent middle conductor. On repeating the typical experiment with this arrangement, we find that the galvanometer indicates a current when connected between the middle loop and either the positive or the negative terminal of the main carbon. I have little doubt but that if we could render the platinum plate in our first used lamp incandescent by concentrating on it from outside a powerful beam of radiant heat, we should get the same result.

A similar set of results can be arrived at by experiments with a bulb constructed like an ordinary vacuum tube, and having small carbon loops at each end instead of the usual platinum or aluminum wires. Such a tube is now before you (see Fig. 13), and will

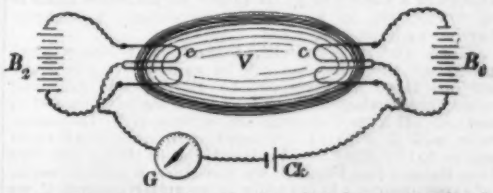


FIG. 13.—Vacuum tube having carbon loop electrodes, *c c*, at each end rendered incandescent by insulated batteries, B_1 B_2, showing current from Clark cell, *Ck*, passing through the high vacuum when the electrodes are incandescent.

not allow the current from a few cells of a secondary battery to pass through it when the carbon loops are

cold. If, however, by means of well insulated secondary batteries we render both of the carbon loop electrodes highly incandescent, a single cell of a battery is sufficient to pass a very considerable current across that vacuous space, provided the resistance of the rest of the circuit is not large. We may embrace the foregoing facts by saying that if the electrodes, but especially the negative electrode, which form the means of ingress and egress of a current into a vacuous space are capable of being rendered highly incandescent, and if at that high temperature they are made to differ in electrical potential by the application of a very small electromotive force, we may get under these circumstances a very sensible current through the rarefied gas. If the electrodes are cold, a very much higher electromotive force will be necessary to begin the discharge or current through the space. These facts have been made the subject of elaborate investigation by Hittorf and Goldstein, and more recently by Elster and Geitel. It is to Hittorf that I believe we are indebted for the discovery of the fact that by heating the negative electrode we greatly reduce the apparent resistance of a vacuum.

Permit me now to pave the way by some other experiments for a little more detailed outline of the manner in which I shall venture to suggest these negative molecular charges are bestowed. This is really the important matter to examine. In seeking for some probable explanation of the manner in which these wandering molecules of carbon in the glow lamp bulb obtain their negative charges, I fall back for assistance upon some facts discovered by the late. Prof Guthrie. He showed some years ago new experiments on the relative powers of incandescent bodies for retaining positive and negative charges. One of the facts he brought forward* was that a bright red hot iron ball, well insulated, could be charged negatively, but could not retain for an instant a positive charge. He showed this fact in a way which is very easy to repeat as a lecture experiment. Here is a gold leaf electroscope, to which we will impart a positive charge of electricity, and project the image of its divergent leaves on the screen. A poker, the tip of which has been made brightly red hot, is placed so that its incandescent end is about an inch from the knob of the electroscope. No discharge takes place. Discharging the electroscope with my finger, I give it a small charge of negative electricity, and replace the poker in the same position. The gold leaves instantly collapse. Bear in mind that the extremity of the poker, when brought in contiguity with the knob of the charged electroscope, becomes charged by induction with a charge of the opposite sign to that of the charge of the electroscope, and you will at once see that this experiment confirms Prof. Guthrie's statement, for the negatively charged electroscope induces a positive charge on the incandescent iron, and this charge cannot be retained. If the induced charge on the poker is a negative charge, it is retained, and hence the positively charged electroscope is not discharged, but the negatively charged electroscope at once loses its charge. Pass in imagination from iron balls to carbon molecules. We may ask whether it is a legitimate assumption to suppose the same fact to hold good for them, and that a hot carbon molecule or small carbon mass just detached from an incandescent surface behaves in the same way and has a greater grip for negative than for positive charge. If this can possibly be assumed, we can complete our hypothesis as follows: Consider a carbon molecule or small collection of molecules just set free by the high temperature from the negative leg of the incandescent carbon horseshoe. This small carbon mass finds itself in the electrostatic field between the branches of the incandescent carbon conductor (see Fig. 14). It is acted upon inductively, and if it behaves like the hot iron ball in Prof. Guthrie's experiment, it loses its positive charge. The molecule then being charged negatively is repelled along the lines of electric force against the positive leg. The forces moving are electric forces, and the repetition of this action would cause a torrent of negatively charged molecules to pour across from the negative to the positive side of the carbon horseshoe. If we place a metal plate in their path, which is in conducting connection with the positive electrode of the lamp carbon, the negatively charged molecules will discharge themselves against it. A plate so placed may catch more or less of this stream of charged molecules which pour across between the heels of the carbon loop. There are many extraordinary facts, which as yet I have been able only imperfectly to explore, which relate to the sudden changes in the direction of the principal stream of these charged molecules, and to their guidance under the influence of magnetic forces. The above rough sketch of a theory must be taken for no more than it is worth, viz., as a working hypothesis to suggest further experiments.

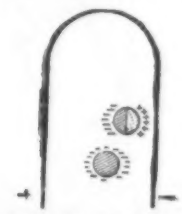


Fig. 14.—Rough diagram illustrating a theory of the manner in which projected carbon molecules may acquire a negative charge.

These experiments with incandescent lamps have prepared the way for me to exhibit to you some curious facts with respect to the electric arc, and which are analogous to those which we have passed in review. If a good electric arc is formed in the usual way, and if a third insulated carbon held at right angles to the other two is placed so that its tip just dips into the arc (see Fig. 15), we can show a similar series of experiments. It is rather more under control if we cause the arc to be projected against the third carbon by means of a magnet. I have now formed on the screen an image of the carbon poles and the arc between them, in the usual way. Placing a magnet at the back of the arc, I cause the flame of the arc to be deflected laterally and to blow against a third insulated carbon held in it. There are three insulated wires attached respectively to the positive and to the negative carbons of the arc, and to the third or insulated carbon, the end of which dips into the flame of the arc projected by the magnet. On starting the arc this third carbon is instantly brought down to the same electrical potential as the negative carbon of the arc, and if I connect this galvanometer in between the negative carbon and the third or insulated carbon, I get, as you see, no indication of a current. Let me, however, change the connections and insert the circuit of my galvanometer in between the positive carbon of the arc and the middle carbon, and we find evidence, by the violent impulse given to the galvanometer, that there is a strong current flowing through it. The direction of this current is equivalent to a flow of negative electricity from the middle carbon through the galvanometer to the positive carbon of the arc. We have here, then, the "Edison effect" repeated with the electric arc. So strong is the current flowing in a circuit connecting the middle carbon with the positive carbon that I can, as you see, ring an electric bell and light a small incandescent lamp when these electric

Fig. 15.—Electric arc projected by magnet against a third carbon, and showing a strong electric current flowing through a galvanometer, G, connected between the positive and this third carbon.

current detectors are placed in connection with the positive and middle carbons.

We also find that the flame-like projection of the arc between the negative carbon possesses a unilateral conductivity. I join this small secondary battery of fifteen cells in series with the galvanometer, and connect the two between the middle carbon and the negative carbon of the arc. Just as in the analogous experiment with the incandescent lamp we find we can send negative electricity along the flame of the arc one way but not the other. The secondary battery causes the galvanometer to indicate a current flowing through it when its negative pole is in connection with the negative carbon of the arc (see Fig. 16), but not when its positive pole is in connection with the negative carbon.

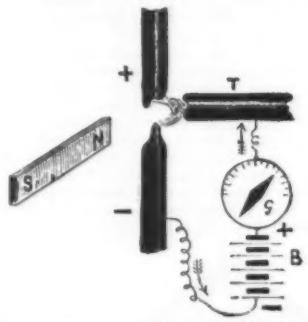


Fig. 16.—Galvanometer, G, and battery, B, inserted in series between negative carbon of electric arc and a third carbon to show unilateral conductivity of the arc between the negative and third carbons.

On examining the third or middle carbon after it has been employed in this way for some time, we find that its extremity is cratered out and converted into graphite, just as if it had been employed as the positive carbon in forming an electric arc.

Time forbids me to indulge in any but the briefest remarks on these experiments; but one suggestion may be made, and that is, that they seem to indicate that the chief movement of carbon molecules in the electric arc is *from* the negative *to* the positive carbon.

The idea suggests itself that, after all, the cratering out of the positive carbon of the arc may be due to a sand-blast-like action of this torrent of negatively charged molecules which are projected from the negative carbon. If we employ a soft iron rod as our lateral pole, we find that, after enduring for some time the projection of the arc against it, it is converted at the extremity into *steel*.

Into the fuller discussion as to the molecular actions going on in the arc, the source and nature of that which has been called the counter electromotive force of the arc, and the causes contributing to produce unsteadiness and hissing in the arc, I fear that I shall not be able to enter, but will content myself with the exhibition of one last experiment, which will show you that a high vacuum, or, indeed, any vacuum, is not necessary for the production of the "Edison effect."

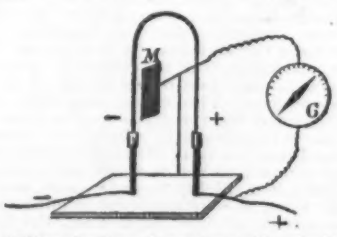


Fig. 17.—"Edison effect" experiment shown with carbon in open air.

Here is a carbon horseshoe-shaped conductor, not inclosed in any receiver (see Fig. 17). Close to the negative leg or branch, yet not touching it, we have adjusted a little metal plate. The sensitive galvanometer is connected between this metal plate and the base of the other or positive leg of this carbon arch. On sending a current through the carbon sufficient to bring it to bright incandescence, the galvanometer gives indications of a current flowing through it, and as long as the carbon endures, which is not, however, for many seconds, there is a current of electricity through it, equivalent to a flow of negative electricity from the plate through the galvanometer to the positive electrode of the carbon. The interposition of a thin sheet of mica between the metal plate and the negative leg of the carbon loop entirely destroys the galvanometer current.*

These experiments and brief expositions cover a very small portion of the ground which is properly included within the limits of my subject. Such fragments of it as we have been able to explore to-night will have made it clear that it is a region abounding in interesting facts and problems in molecular physics. The glow lamp and the electric arc have revolutionized our methods of artificial lighting, but they present themselves also as subjects of scientific study, by no means yet exhausted of all that they have to teach.

A SIMPLE INTERFERENCE EXPERIMENT.

By Albert A. Michelson.

There is probably no experiment connected with the wave theory of light of greater fundamental importance than the justly celebrated one known as "Fresnel's mirror experiment," and accordingly many find it necessary to repeat the experiment for their own edification or for class demonstration.

Without the use of rather elaborate and costly apparatus even skilled experimenters find some difficulty in producing the desired effect—the interference of two pencils of light as manifested by the appearance of colored fringes on a screen, or in the focus of an observing lens; and unskilled observers find it almost impossible, even with these aids. Even when produced under the most favorable conditions, the phenomenon is complicated and often much obscured by diffraction effects.

A very considerable improvement is effected by the substitution of Fresnel's "bi-prism," though in this case one of the chief points of interest is lost, namely, the change of breadth of the bands with alternation of angle. The phenomenon is also complicated by the dispersion of the glass.

The following method has the advantage of being easily within the reach of even unskilled persons, and of giving the required result in all its purity.

Fasten a piece of plane glass, *ab*, Fig. 1 (selected plate

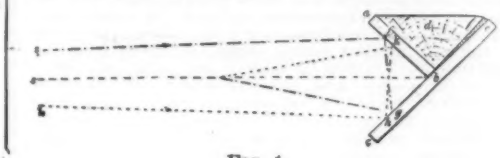


Fig. 1.

glass will answer, though sextant glass is much better), to a right angled prism of wood, *d*; then press *d* against a second piece of plane glass, *ce*, by means of a little soft wax, so that the angle, *a b c*, is a little less than a right angle. If the light from a distant electric arc lamp be allowed to fall on the glasses (which should be silvered on the front surfaces), two rays, *s*, $s_{,,}$, starting in the same phase, after reflections at *f*, *g* and *h*, *k*, respectively, will meet somewhere in the line, *b s*, in the same phase, the two paths being exactly equal.† Accordingly this line is the locus of the central bright fringe and the system of fringes may readily be observed through a lens of about an inch focal length whose axis is anywhere along this line.

The figure is drawn for clearness in the vertical plane containing the source, and if the intersection of the two surfaces (projected at *b*) were at right angles with *s b*, it would be necessary to deflect part of the light to one side by a transparent mirror. But the appearance of the fringes is in nowise changed if the apparatus be rotated through a horizontal angle, *a*. The line *b s* is then rotated through 2*a*, and there is no difficulty in observing the fringes directly.

It will be noted that no adjustments whatever are necessary.

All that is required is that the surfaces be fairly true and the angle slightly less than 90°. This last condition can be readily fulfilled by making the two images of a distant object nearly coincide.

The following may serve as a guide to the general disposition of the apparatus. Fig. 2.

Fig. 2.

L is the arc lamp (if provided with a shade, the latter should be transparent), *m m* the two mirrors, *f* the fringes in the focus of the lens *l*, the eye being at an equal distance on the other side of the lens. L *m* may be 100 meters and *m f* one meter or more.

The fringes under these conditions appear as a series of fine lines parallel to the intersection of the surfaces *a b* and *b c*.

If the source be distant and the angle between the mirrors, 90 — *a*, and the wave length, λ, then it may readily be shown that the width of the fringes is $\lambda / 4a$.

—*Amer. Jour. Science.*

* "On a New Relation between Electricity and Heat," *Phil. Mag.*, vol. xlv., p. 308 (1873).

* This last experiment is due to my assistant, Mr. A. H. Bate.

† This is true whether the surfaces form equal angles with *s b* or not.

HISTORY OF THE WHEELBARROW.

IN most of the biographical articles upon Blaise Pascal, it is said, apropos of the mechanical labors of the great philosopher, that we owe to him the invention of the dray and the vinegar maker's wheelbarrow. The authors of a large number of technical works and dictionaries, Bouillet especially, in his *Dictionnaire*

FIG. 1.—WHEELBARROW FIGURED IN A MS. OF THE THIRTEENTH CENTURY.

des Sciences, have repeated that the wheelbarrow was invented by Pascal, that is to say, along about the middle of the seventeenth century.

In Littre's dictionary of the French language, on another hand, we read under the word *brouette:*

"Wheelbarrows were invented by a Mr. Dupin in 1669." The construction of these vehicles, according to Littre, was therefore posterior to Pascal, who died in 1662.

Having had an opportunity of examining a curious work of the sixteenth century, the Cosmographie of Sebastien Munster (edition of 1555), we have remarked in this old book a curious wood engraving in which is clearly figured a single-wheeled barrow pushed along by a laborer. We reproduce this engraving herewith, along with another plate from the same book in which we see represented a tramway car running upon rails. We have, therefore, certain proof of the existence of the wheelbarrow in the middle of the sixteenth century, that is to say, about a hundred years before Pascal.

The history of the wheelbarrow assuredly is not of sufficient importance to allow us to think of occupying ourselves further with it after citing Sebastien Munster's book as a matter of curiosity, but chance has led us to collect some new data in regard to the subject that have appeared to us worthy of mention.

Last year, at the retrospective exhibition of means of carriage, Mr. Bixio, who organized his exhibition of carriages and vehicles of all kinds, alongside of our aeronautic exhibition, told us that the wheelbarrow existed far back of the sixteenth century, and that its origin was to be found in the thirteenth.

This time we find ourselves much in advance of Pascal.

Mr. F. Guerrero, Mr. Bixio's colaborer, has been good enough to make known to us the curious discoveries that he has made in the innumerable manuscripts of the National Library belonging to epochs anterior to the discovery of printing.

We reproduce in Fig. 1 a facsimile of a miniature taken from the history of Holy Grail. The manuscript is of the thirteenth century, and the miniature that we reproduce is marginal and is somewhat crudely drawn; but it gives a perfectly defined image of a man who is pushing along another one in a single-wheeled barrow absolutely identical with those still everywhere used in cities and the country.

In a manuscript of the fourteenth century, entitled *Vita et passio Dionysii Aeropagi*, we may see a wheelbarrow of another style, which is much used at the present time, and which serves this time for the carriage of a load (Fig. 2).

Upon reaching an epoch much less distant from our own, the manuscripts become more and more artistic.

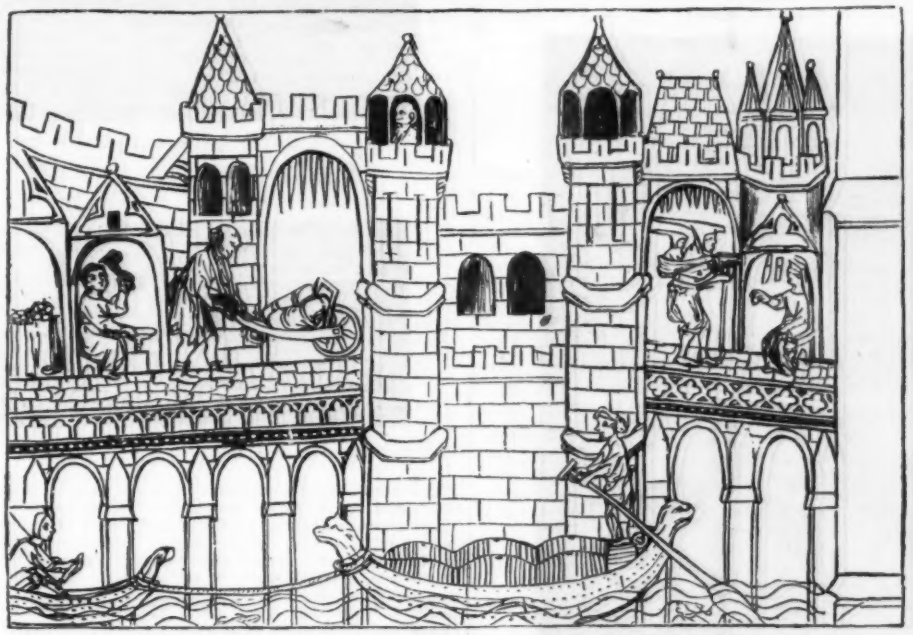


FIG. 2.—WHEELBARROW FIGURED IN A MS. OF THE FOURTEENTH CENTURY.

In the fifteenth century they contain miniatures which are remarkable as regards delicacy of drawing and beauty of coloring. Among the riches of the National Library, we find documents, too, that represent the wheelbarrow of former centuries.

In Fig. 3 we have a facsimile of a magnificent miniature of the fifteenth century, taken from a manuscript entitled *La Vie et les Miracles de Notre Dame*. This miniature is painted with genuine art, and its state of preservation leaves nothing to be desired. The scene represents an asylum where nuns are attending to the wounded, lame, bandy legged, paralytics, etc. It is assuredly a wounded person that is being brought in in a wheelbarrow, and this would seem to indicate that the wheelbarrow was sometimes used for the carriage of the infirm or impotent. It may be that it was a wounded person that the thirteenth century draughtsman meant to figure in the simple composition that we mentioned in the first place (Fig. 1).

Fig. 4 reproduces another miniature of the fifteenth

FIG. 4.—WHEELBARROW FIGURED IN A MINIATURE OF THE FIFTEENTH CENTURY.

century taken from a very remarkably illustrated Quintus Curtius. Here the barrow represented in the foreground serves for the carriage of building materials. It will be observed that the laborer facilitates his work by the use of a strap passing around his shoulders.

It results from what we have said that the wheelbarrow evidently existed as far back as the thirteenth century, and it would not be surprising to find that this modest and convenient vehicle dates far back of that epoch. We should willingly believe it. However that may be, the authors of future dictionaries will do well to expunge the passages in which their predecessors assert that the origin of the wheelbarrow dates back to the seventeenth century.

Pascal, moreover, is rich enough to allow the invention of the wheelbarrow to be taken away without the loss of any of his glory.

As a philosophical conclusion to be drawn from our study, we may observe that history is an inexhaustible domain, and that among ancient books and manuscripts we may find things and make discoveries just as the archeologist does in the bowels of the earth. We may add also that an error once printed is often reproduced in a whole series of works whose authors borrow their statements one from another, instead of going back to the original sources. The history of the wheelbarrow furnishes a striking example of this.—*La Nature.*

FIG. 3.—WHEELBARROW FIGURED IN A MINIATURE OF THE FIFTEENTH CENTURY.

THE MUSICAL BELLOWS.

THE instrument herewith illustrated is merely the ordinary hand bellows that was met with a hundred and even a fewer years ago, not only in all the kitchens, but also in all the drawing rooms of France and Navarre. At present, thanks to the discovery of coal and also to the improvement in heating apparatus, it has fallen into desuetude, and, before long, there will be generations to which it will be totally unknown.

If we wish to make use of one as a musical instrument, there is no need of having it made expressly for the purpose. No, the bellows such as it is can be very well utilized without previous preparation. Nevertheless, we add that if the bellows contains no holes or imperfections, and if it is provided with a well adjusted nozzle which is very smooth internally, it will be so much the better. The bellows as we find it at the

THE MUSICAL BELLOWS.

hard wareman's, is usually provided with a small collar at the end of the nozzle. As this is useless and would incommode the player, it is better to remove it. This may be done by grasping it with a pair of nippers and giving it a slight twist; a little filing to remove the roughness, and all is ready The following is the mode of playing on this original instrument.

Hold the bellows straight before the breast, the end resting against the lower lip, the fixed handle in the left hand, and the movable one in the right. The upper lip should be thrust slightly outward so as to form an obstacle to the wind that escapes from the bellows. If we maneuver it in this position, we shall succeed, after a few tentatives, and with a little patience, in producing a sound. Perhaps this will not be harmonious for a beginning, but it will at all events be a sound, and where there is *sound*, there is music.

The wind, of course, must all be furnished by the bellows, and all the player has to do is to widen or contract the labial orifice, and to enlarge and reduce the buccal cavity. Do not despair if you do not succeed at first. Neither did we succeed in the beginning, and do you know how many notes we make? Nearly three octaves, and we play all the airs that we care to, and that too without any fatigue of the chest, since it is not we who blow.

In order to produce grave notes, try to form a large cavity in the mouth, and, at the same time, to round the lips. In order to give more intensity to the notes, blow harder. When you have had sufficient practice, you will be able to make with this instrument what string instruments alone can make, that is, the quarter tones. The sharp notes as in all wind instruments require more labor than the bass ones, which also require more than the intermediate notes.

It is unnecessary to say that in order to play this instrument it is indispensable to have an ear, for the notes are not produced mechanically, as may be easily understood. It is also evident that a person can play the bellows without being the least of a musician.

We have played bellows and flute duos with piano accompaniment, and can assert that the effect was very fine, and much appreciated by the auditors. We have sometimes played alone bellows and piano duos. This is the way we did it: We attached the bellows to our breast by a belt buckled tightly behind the back, and while the right hand produced the song, the left played upon the piano a brief but sufficient accompaniment.—*La Nature.*

ON A NEW METHOD AND DEPARTMENT OF CHEMICAL RESEARCH.*

By Dr. G. GORE, F.R.S.

IN an investigation "On the Change of Potential of a Voltaic Couple by Variation of Strength of its Liquid" (Roy. Soc. Proc., 1888, xliv., p. 296), I showed that by immersing a small pair of unamalgamated zinc and platinum plates in distilled water, and then adding to the water successive small and equal quantities of a particular halogen, acid, or salt, until a more or less saturated solution was formed, and measuring by the method of balance with a galvanometer in the circuit, with a suitable thermoelectric pile (see Proc. Birm. Phil. Soc., iv., p. 130; also *The Electrician*, 1884, xii., p. 414), aided when necessary by a zinc-platinum distilled water cell, or a Clark's standard cell, the degrees of electromotive force produced by each addition of substance, the changes of that force did not vary by a regular gradation. And I stated that "by plotting the quantities of dissolved substance as ordinates to the degrees of electromotive force as abscissæ, each substance or mixture of substances yielded a different curve of electromotive force on uniformly changing the degree of strength of its solution." And that "with a given voltaic couple at a given temperature, the curve was constant and characteristic of the substance." The examples given in this paper illustrate these statements, and the measurements were made by the above method.

Instead of employing a thermopile, the following plan with the "voltaic balance" might be adopted: 1st. Balance two small zinc-platinum voltaic cells with distilled water in each, and a galvanometer of 100 ohms resistance in the circuit, then add gradually sufficient of the exciting substance to one of the cells to just visibly upset the balance, and note the quantity added. 2d. Balance the cells with a very weak solution containing one unit quantity of the substance in each cell; then add a sufficient excess of the substance to one cell to again upset the balance, and note the amount of excess. 3d. Balance the cells with a two unit quantity solution, and upset the balance again in like manner. And so on through such a series of strengths of solution as may be desired to obtain a curve. The proportions of excess of substance added to the amount of water in the cell represent the relative amounts of voltaic energy of the different strengths of liquid.

This method is very much more sensitive than the one with the thermopile, for while the latter only divides the range of difference of potential between water and chlorine for example (=0·753 volt) in practical working into about 15,000 parts, the former divides it into 1,200 millions. On the other hand, while by the thermopile method the values of the unit of measurement are equal throughout the series, those of the numbers obtained by the voltaic-balance one vary with the degree of strength of the solution. The following instance illustrates this:

The liquid employed was a solution of potassium sulphate, and the balancing couples were formed of zinc and platinum. The table shows the degrees of strength of the solution, and the proportions of additional salts required with each to upset the balance.

Strength of Solution. K_2SO_4.	Water.	Excess of K_2SO_4. K_2SO_4.	Water.
1·0 grain	155 grains.	0·30 grain	= 1 in 51·6
0·5 "	" "	0·25 "	= 1 in 60·0
0·1 "	" "	0·20 "	= 1 in 77·5

The degree of sensitiveness of the balance therefore increased directly as the degree of the dilution of the solution.

A. CURVES OBTAINED BY VARYING THE STRENGTH OF THE SOLUTION AT BOTH METALS.

Nearly all the measurements of electromotive force given in this paper were made with highly pure substances, and in section "A," with the exception of one instance only (see Fig. 8), each curve starts from the potential of unamalgamated zinc and platinum in distilled water at about 16° C. = 1·127 volt. The quantity of distilled water employed as the solvent was in nearly every case 155 grains, and the series of degrees of strength of the solutions of each substance were usually such as could be worked by the process, *i. e.*, neither too strong nor too weak, and were with different substances either the same or so arranged as to best enable comparisons to be made between the results of the different series of measurements; they were not always sufficiently strong to fully develop the most characteristic curves.

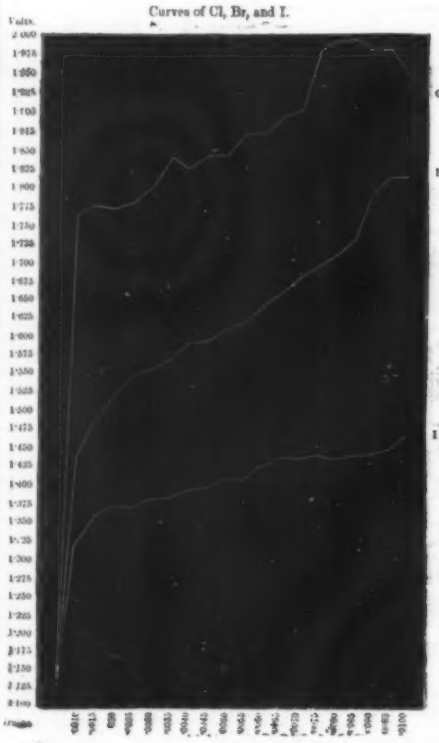
For each separate measurement, with the solutions of the halogens and the strong ones of the acids, a fresh portion of the original liquid was taken; with those of other substances the zinc was so feebly acted upon and the liquid so slightly altered in composition, that this was not found necessary. With solutions of salts, the presence of films of oxide upon the zinc was tested for by replacing the saline liquid by distilled water, and then observing whether the cell was still exactly balanced by a zinc-platinum water one. No trouble was experienced from polarization caused by hydrogen in the platinum plates, nor by atmospheric air dissolved in the water.

1. *Curves of Chlorine, Bromine and Iodine.*

The range of strength of the solutions of each substance was from 0·001 to 0·01 grain in 155 grains of water. With solutions of these substances the degree of electromotive force increased somewhat with the period of immersion; this difficulty was due to the great chemical energy of the substances, and was overcome by making the fluctuations of the galvanometer needles equal on each side of zero.

Fig. 1.

Curves of Cl, Br, and I.



These curves show: 1st. An increase generally of electromotive force attending increased strength of solution. 2d. A much greater increase caused by the first amount of substance added than by the subsequent additions. 3d. A gradation of degree, both of first increase and of maximum electromotive force in the three curves, varying inversely as the magnitudes of the atomic weights of the substances. 4th. A general similarity of form, sufficient to show a graduated degree of likeness. And 5th. A sufficient degree of difference of form to characterize each individual substance.

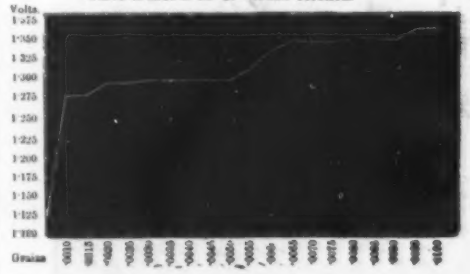
2. *Curves of* HCl, HBr, *and* HI.

a. Weak Solutions.

Each acid was pure and colorless. The solutions were of the same range of degrees of strength as those of the halogens, in order to compare the effects of the two groups of substances; and the curves are all drawn on the scale of magnitude in each direction as those of the halogens.

Fig. 2.

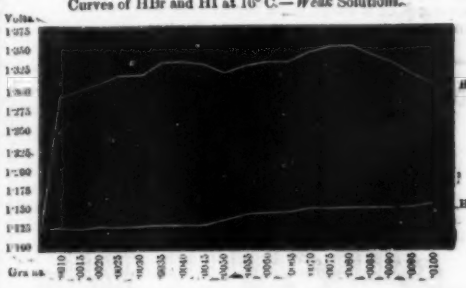
Curve of HCl at 10° C.—*Weak* Solution.



The curves show: 1st. That the union of hydrogen with the halogens greatly diminished the electromotive force. 2d. A feeble increase of electromotive force, greatest at the commencement, especially with hydrochloric and hydrobromic acids, attending increased strength of the solution. 3d. A less degree of family likeness than in the curves of the halogens. 4th. The substance of largest molecular weight gave the smallest increase of electromotive force. And 5th. Each substance gave a characteristic curve. The general feebleness of character of the curves was due to the weakness of the solutions (compare Fig. 7, of curves of solutions 100 times stronger).

Fig. 3.

Curves of HBr and HI at 16° C.—*Weak* Solutions.



3. *Curves of* HNO_3 *and* H_2SO_4.

The acids were pure and the range of degrees of strength of their solutions was the same as those of the weak ones of hydrochloric, hydrobromic, and hydriodic acids.

Fig. 4.

Curve of HNO_3 at 14° C.—*Weak* Solution.

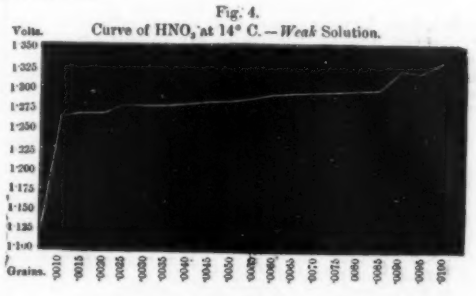
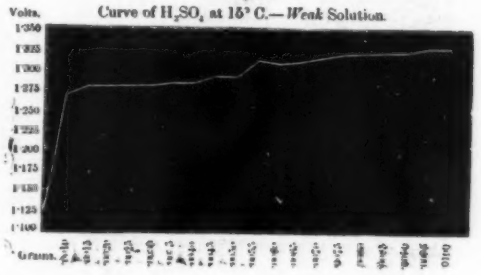


Fig. 5.

Curve of H_2SO_4 at 15° C.—*Weak* Solution.



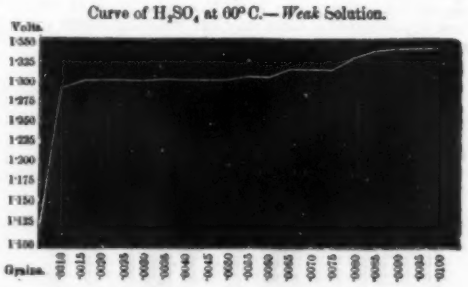
The curves are drawn upon the same scale as those of the weak solutions of the above named acids. 1st. They are very greatly different from those of the halogens, and show very much smaller degrees of electromotive force. 2d. Their differences from those of hydrochloric, hydrobromic, and hydriodic acid of the same range of degrees of strength are also quite conspicuous. And 3d. They are sufficiently unlike to be characteristic of each substance and to be clearly distinguishable from each other. The solutions employed were too weak to fully show the characteristic forms of the curves; the degrees of strength were chosen chiefly to enable the curves to be compared with those yielded by the halogens and by their acids.

4. *Curve of* H_2SO_4 *at* 60° C.

The range of degrees of strength of the solution was the same as in the previous case, viz., from 0·001 to 0·01 grain of the substance in 155 grains of water.

Fig. 6.

Curve of H_2SO_4 at 60° C.—*Weak* Solution.



By comparing the curves obtained at the two different temperatures, we find that a rise of temperature caused a general increase of electromotive force, greatest at the commencement, and quite sufficient to distinguish the one curve from the other. The difference would probably be much greater with stronger solutions (compare Figs. 9 and 10 of KBr at 18° C. and 60° C.)

5. *Curves of* HCl, HBr, *and* HI.

b. Strong Solutions.

These solutions were one hundred times stronger than the previous ones, in order to fit them for comparison with those of the corresponding salts; they contained from 0·10 to 1·0 grain of substance in 155 grains of water. The degrees of electromotive force of the solution of hydrochloric acid were variable, and those of the other two acids less so.

These curves are drawn upon a scale 2·92 times as large vertically as those of the previous ones, in order to fit them for comparison with those of the corresponding salts. They show: 1st. A general increase of electromotive force attending gradually increased strength of liquid. 2d. A much larger increase pro-

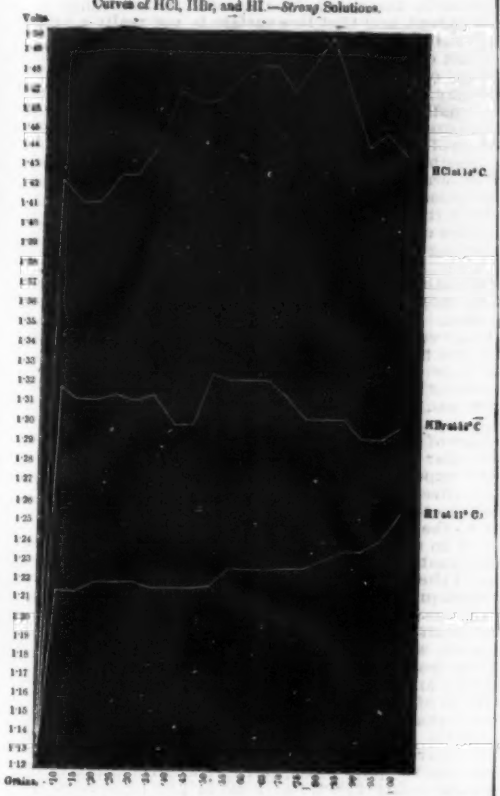
* From the *Philosophical Magazine* for May, 1890.

duced by the first amount of substance added than by the succeeding ones. 3d. A gradation of degree of general increase of such force varying inversely as the magnitudes of the molecular weights of the substances. And 4th. A great dissimilarity of form characteristic of each individual substance.

By comparison with the curves yielded by the weak solution of the three acids, those of the strong ones show: 1st. A much greater increase of electromotive

Fig. 7.

Curves of HCl, HBr, and HI.—*Strong* Solutions.



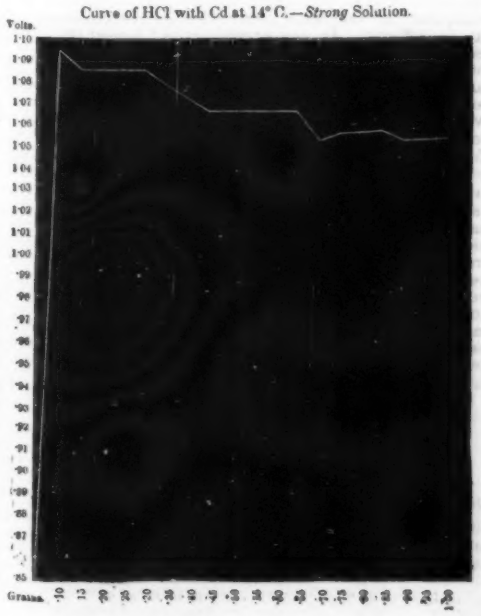
force, both on the addition of the first amount of the substance and by the subsequent additions. 2d. A more distinct relation of those increases to the magnitudes of the molecular weights of the substances. 3d. Much more characteristic curves. And 4th. A much greater degree of irregularity of form of curve; this greater irregularity of form was a genuine effect, and was not due to temporary fluctuations of the current.

6. *Curves of* HCl *with Cadmium as Positive Metal.*

The range of degrees of strength of the solutions in this case was the same as that of the "strong" solution of the same acid in the immediate previous group of acids, and the scale of magnitude upon which the curve is drawn is the same. The electromotive force was variable, owing to the strength of the solutions, and of course started from a lower point than when zinc was used as the positive metal.

Fig. 8.

Curve of HCl with Cd at 14° C.—*Strong* Solution.



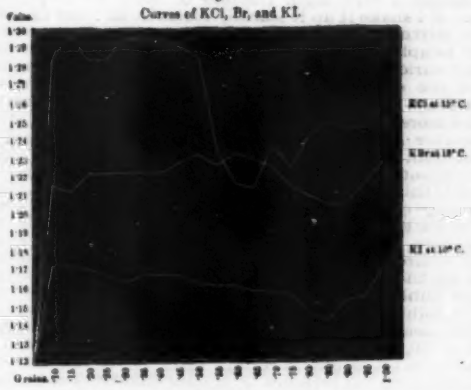
On comparing the curve with the one yielded by zinc in the same degrees of strength of solution of the same acid, we find: 1st. Quite a different form of curve. 2d. A smaller increase of electromotive force on adding the first portion of acid. 3d. A general decrease of that force by the further additions. And 4th. A curve characteristic of the substance.

7. *Curves of* KCl, KBr, *and* KI.

All the substances were highly pure, colorless, and inodorous; the iodide was very faintly alkaline. The solutions were of the same range of degrees of strength as the strong ones of the corresponding acids, viz., from 0·1 to 1·0 grain of substance in 155 grains of water. The electromotive force of the zinc-platinum couple increased somewhat with the period of immersion. The absence of solid films upon the zinc was proved by occasionally replacing the saline liquid by distilled water, and observing whether the cell was still exactly balanced by a zinc-platinum water one.

Fig. 9.

Curves of KCl, Br, and KI.



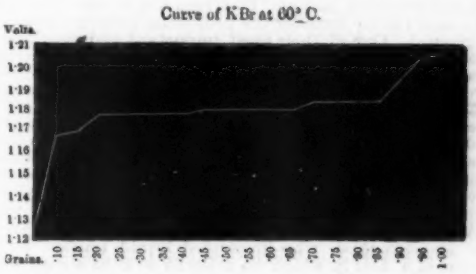
The curves of these substances are all drawn upon the same scale of magnitude as those of the "strong" solutions of the corresponding acids. They show: 1st. A much greater increase of the electromotive force caused by the first amount of substance added than by the subsequent ones. 2d. A gradation of degrees of first increase and of maximum electromotive force, varying inversely as the magnitudes of molecular weight of the substances. 3d. Large differences of form, characteristic of each individual substance. And 4th. The substitution of potassium for hydrogen in the corresponding acids lowered the electromotive force in all three cases, and the amount of this reduction varied inversely as the magnitudes of the molecular weights of the substances; the union of potassium with the halogens had similar effects, but in much greater degrees (compare the respective figures).

8. *Curve of* KBr *at* 60° C.

The range of degrees of strength of the solution in this case was the same as in the previous one when the liquid was at 18° C., and was from 0·10 to 1·0 grain of substance in 155 grains of water.

Fig. 10.

Curve of KBr at 60° C.



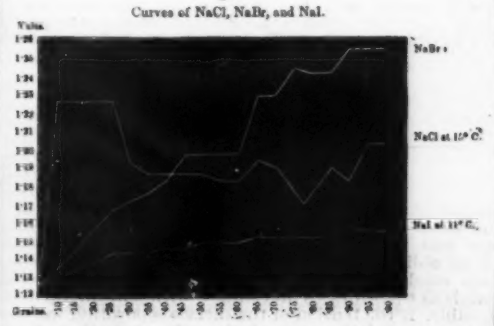
On comparing the two curves obtained at the two temperatures we find considerable differences, viz.: 1st. A great unlikeness of general form. 2d. A general and large diminution of electromotive force at the higher temperature. And 3d. A much smaller increase of that force on the addition of the first portion of the substance. The differences would probably have been less conspicuous if the solutions in each case had been much weaker. These results support the conclusion that potassium bromide behaves to a certain extent like a different substance at each different temperature.

9. *Curves of* Na Cl, Na Br, *and* Na I.

The chloride contained a trace of sulphate, and the bromide and iodide were very faintly alkaline. The solutions were of the same range of degrees of strength as the corresponding salts of potassium; and the curves are drawn upon the same scale of magnitude.

Fig. 11.

Curves of NaCl, NaBr, and NaI.



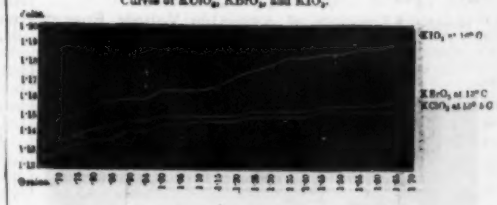
These curves show: 1st. A general increase of electromotive force by increase of dissolved substance. 2d. A great difference of form, and strongly characteristic curve in each case. And 3d. The substitution of sodium for potassium in each salt considerably reduced the degree of electromotive force produced by the first addition of the substance, and the amount of this reduction varied inversely as the molecular weights of the salts. The curves are widely different in form from those of the corresponding salts of potassium, and this is no doubt entirely due to the difference of metallic base; in each group, however, the curve of the chloride intersects that of the bromide.

10. *Curves of* $KClO_3$, $KBrO_3$, *and* KIO_3.

The chlorate contained a trace of chloride. In consequence of the degrees of electromotive force produced by solutions of these salts being so little greater than that produced by water alone, viz., 1·127 volts, it was necessary to use much stronger solutions than those of the previous substances; the ones employed contained from 0·7 to 1·7 grains in 155 grains of water.

Fig. 12.

Curves of $KClO_3$, $KBrO_3$, and KIO_3.



The curves show: 1st. A striking similarity of general form, very different from that of the corresponding chloride, bromide, and iodide; this was probably chiefly due to the general feebleness of action. 2d. A very small increase of electromotive force in each case on adding the first portion of substance, and on subsequent additions; and the amounts of these increases, contrary to what happened with other groups of substances, varied *directly* as the magnitudes of the molecular weights of the salts, but the degree of reversed action was not conspicuous. 3d. A sufficient difference of form to characterize each substance. And 4th. The chemical union of oxygen with the three corresponding halogen salts reduced the general electromotive force in each case, and the amount of reduction varied inversely as the magnitudes of the molecular weights of the salts (compare Fig. 9).

11. *Curves of* K_2SO_4 *and* Na_2SO_4.

The potassium salt was very pure; the sodium one contained traces of chloride. The solutions were of the same range of degrees of strength as those of the halogen salts of the same metals, viz., from 0·1 to 1·0 grain of salt in 155 grains of water.

Fig. 13.

Curve of K_2SO_4 at 14·5° C

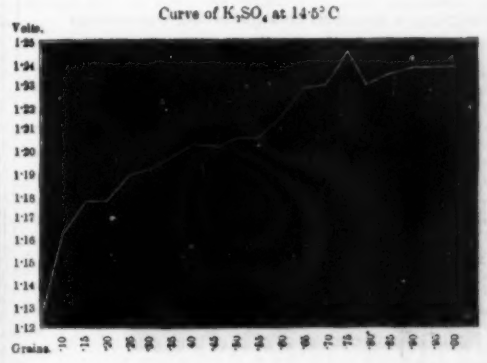
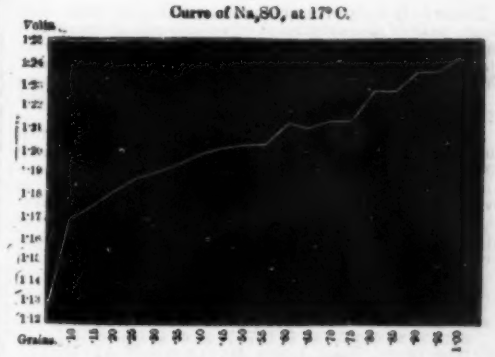


Fig. 14.

Curve of Na_2SO_4 at 17° C.



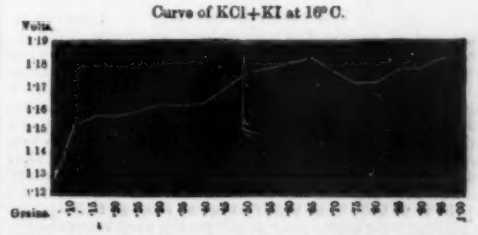
These two curves are largely alike, due to their being those of closely allied salts of the same acid; but somewhat different in consequence of difference of their metallic bases. They are both considerably different from those of the chlorides, bromides and iodides of the same metals.

12. *Curves of* KCl + KI, *and* KCl + NaCl.

The measurements of electromotive force of these were made to ascertain the influence of more complex compounds upon the amount of that force. The salts were mixed in the proportions of their molecular weights, and the proportions of mixtures taken were the same as those of the same salts separately in previous experiments, viz., from 0·1 to 1·0 grain in 155 grains of water.

Fig. 15.

Curve of KCl+KI at 16° C.



1. Each of the curves is strikingly unlike in general form each of those of the constituent salts of the compound, and the form is not in either case an average of that of the two; each of them also shows a great reduction of electromotive force due to the chemical union of the two constituents.

2. In each case an increase of strength of solution is attended by an increase of electromotive force.

3. The two curves are each characteristic of the individual substances.

The amounts of voltaic energy of the dissolved salts separately before chemical union were:

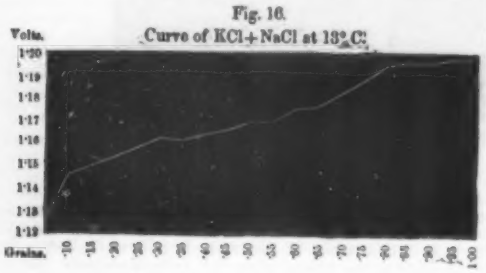
KCl = 699,803, NaCl = 207,589, and KI = 16,361;

and after the union those of the compounds were:

KCl + KI = 7,571, and KCl + NaCl = 5,959

(see "Relative Amounts of Available Voltaic Energy

Fig. 16.

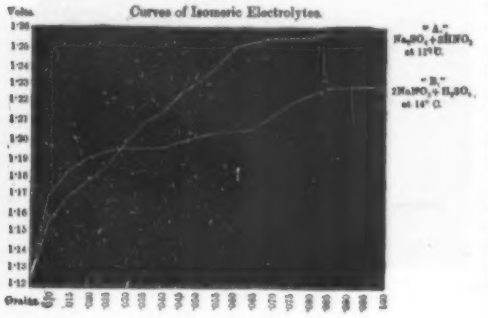


of Aqueous Solutions," Proc. Birm. Phil. Soc., vii., part i.)

13. *Curves of Isomeric Electrolytes.*

I have already shown (see Phil. Mag., October, 1889, p. 289, "On the Molecular Constitution of Isomeric Solutions") that aqueous isomeric electrolytes yield different amounts of voltaic energy with a zinc-platinum couple. In the present case I employed the same pair of mixed aqueous solutions as were used in that research, viz., an unstable one "A" having a composition represented by the formula $Na_2SO_4 + 2HNO_3$, and yielding an average voltaic energy = 77,446; and its stable isomer "B" represented by $2NaNO_3 + H_2SO_4$, and yielding 32,723. The degrees of strength of the series of solutions employed were those which were the most easily worked, and were from 0·01 to 0·1 grain of the mixture in 155 grains of water. The constituent solutions of "A," previous to being mixed, contained 0·01 grain of substance per cubic centimeter; if they were stronger than this, there was risk of the liquid undergoing a chemical change during the mixing.

Fig. 17



These curves show much more completely than any single pair of measurements of voltaic energy could do the considerable differences between the molecular and chemical constitutions of the two liquids. Nearly throughout its entire range the curve of "A" shows a greater degree of electromotive force than that of "B."

As the unstable liquid "A" is readily changed into the stable one "B" by merely heating it to nearly 100° C. in a stoppered glass flask during fifteen minutes, and then would give the curve of "B," it is evident that the method of examining aqueous solutions by means of curves of electromotive force is applicable for detecting and measuring chemical and molecular changes in them.

(*To be continued.*)

FOAM.*

By the Right Hon. LORD RAYLEIGH, M.A., D.C.L., LL.D., F.R.S., Prof. of Natural Philosophy, R. I.

WHEN I was turning over in my mind the subject for this evening, it occurred to me to take as the title of the lecture, "Froth." But I was told that a much more poetical title would be "Foam," as it would so easily lend itself to the appropriate quotations. I am afraid, however, that I shall not be able to keep up the poetical aspect of the subject very long; for one of the things that I shall have most to insist upon is that foaming liquids are essentially impure, contaminated—in fact, dirty. Pure liquids will not foam. If I take a bottle of water and shake it up, I shall get no appreciable foam. If, again, I take pure alcohol, I get no foam. But if I take a mixture of water with 5 per cent. of alcohol, there is a much greater tendency. Some of the liquids we are most familiar with as foaming, such as beer or ginger beer, owe the conspicuousness of the property to the development of gas in the interior, enabling the foaming property to manifest itself; but of course the two things are quite distinct. Dr. Gladstone proved this many years ago by showing that beer from which all the carbonic acid had been extracted in vacuo still foamed on shaking up. I now take another not quite pure but strong liquid, acetic acid, and from it we shall get no more foam than we did from the alcohol or the water. The bubbles, as you see, break up instantaneously. But if I take a weaker acid, the ordinary acid of commerce, there is more, though still not much, tendency to foam. But with a liquid which for many purposes may be said to contain practically no acetic acid at all, seeing that it consists of water with but $\frac{1}{1000}$ part of acid, the tendency is far stronger, and yet we get a very perceptible amount of foam.

These tests with the alcohol and acetic acid are sufficient to illustrate the principle that the property of foaming depends on contamination. In pure ether we have a liquid from which the bubbles break even more quickly than from alcohol or water. They are gone in a moment. In some experiments I made at home I found that water containing a small proportion of ether foamed freely; but on attempting two or three days ago to repeat the experiment, I was surprised to find a result very different. I have here some water containing a very small fraction of ether, about $\frac{1}{1000}$ part. If I shake it up it scarcely foams at all; but another mixture made in the same proportion from another sample shows more tendency to foam. This is rather curious, because both ethers were supposed to be of the same quality; but one had been in the laboratory longer than the other, and perhaps contained more greasy matter in solution.

Another liquid which foams freely is water impregnated with camphor. Camphor dissolves sparingly; but a minute quantity of it alters the characteristics of water in this respect. Another substance, very minute quantities of which communicate the foaming properties to water, is glue or gelatine. This liquid contains only three parts in 100,000 of gelatine, but it gives a froth entirely different from that of pure water. Not only are there more bubbles, but the duration of the larger bubbles is quite out of proportion to that of water bubbles. This sample contains five parts in 100,000, nearly double as much; but even with but one part in 100,000, the foaming property is so evident as to suggest that it might in certain cases prove valuable for indicating the presence of minute quantities of impurities. I have been speaking hitherto of those things which foam slightly. They are not to be compared with say a solution of soap in water, which, as is well known to everybody, froths very vigorously. Another thing comparable to soap, but not so well known, is saponine. It may be prepared from horse chestnuts by simply cutting them in small slices and making an infusion with water.

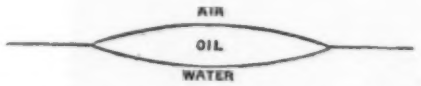
A small quantity of this infusion added to water makes it foam strongly. The quantity required to do this is even less than in the case of soap; so the test is more delicate. It is well known that rivers often foam freely. That is no doubt due to the effect of saponine or some analogous substance. Sea water foams, but not, I believe, on account of the saline matter it contains; for I have found that even a strong solution of pure salt does not foam much. I believe it has been shown that the foaming of sea water, often so conspicuous, is due to something extracted from seaweeds during the concussion which takes place under the action of breakers.

Now let us consider for a moment what is the meaning of foaming. A liquid foams when its films have a certain durability. Even in the case of pure water, alcohol, and ether, these films exist. If a bubble rises, it is covered for a moment by a thin film of the liquid. This leads us to consider the properties of liquid films in general. One of their most important and striking properties is their tendency to contract. Such surfaces may be regarded as being in the condition of a stretched membrane, as of India rubber, only with this difference, that the tendency to contract never ceases. We may show that by blowing a small soap bubble, and then removing the mouth. The air is forced back again by the pressure exerted on the bubble by the tension of the liquid. This ancient experiment suffices to prove conclusively that liquid films exercise tension.

A prettier form of the same experiment is due to Van der Mensbrugghe, who illustrated liquid tension by means of a film in which he allowed to float a loop of fine silk, tied in a knot. As long as the interior of the loop, as well as the exterior, is occupied by the liquid film, it shows no tendency to take any particular shape: but if, by insertion of say a bit of blotting paper, the film within the loop be ruptured, then the tension of the exterior film is free to act, and the thread flies instantaneously into the form of a circle, in consequence of the tendency of the exterior surface to become as small as possible. The exterior part is now occupied by the soap film, and the interior is empty. Many other illustrations of this property of liquids might be given, but time does not permit.

In the soap film, as in the films which constitute ordinary foam, each thin layer of liquid has two surfaces; each tends to contract; but in many cases we have only one such surface to consider, as when a drop of rain falls through the air. Again suppose that we have three materials in contact with one another—water, oil, and air. There are three kinds of surfaces separating the three materials, one separating water and oil, another oil and air, and a third surface separating the water from the air. These three surfaces all exert a tension, and the shape of the mass of oil depends upon the relative magnitudes of the tensions. As I have drawn it here (Fig. 1), it is implied that the

FIG. 1.



tension of the water-air surface is less than the sum of the other two tensions—those of the water-oil surface and the air-oil surface; because the two latter acting obliquely balance the former. It is only under such conditions that the equilibrium of the three materials as there drawn in contact with one another is possible. If the tension of the surface separating water and air exceed the sum of the other two, then the equilibrium as depicted would be impossible. The water-air tension, being greater, would assert its superiority by drawing out the edge of the lens, and the oil would tend to spread itself more and more over the surface.

And that is what really happens. Accurate measurements made by Quincke and others show that the surface tension separating water and air is really greater than the sum of the two others. So oil does tend to spread upon a surface of water and air. That this is the fact we can prove by a simple experiment. At the feet of our chairman, our honorary secretary, is a large dish, containing water which at present is tolerably clean. In order to see what may happen to the surface of the water, it is dusted over with fine sulphur powder, and illuminated with the electric light. If I place on the surface a drop of water, no effect ensues; but if I take a little oil, or better still a drop of saponine, or of soap water, and allow that to be deposited upon the middle of the surface, we shall see a great difference. The surface suddenly becomes dark, the whole of the dust being swept away to the boundary. That is the result of the spread of the film, due to the presence of the oil.

How then is it possible that we should get a lens-shaped mass of oil, as we often do, floating upon the surface of water? Seeing that the general tendency of oil is to spread over the surface of water, why does it not do so in this case? The answer is that it has already spread, and that this surface is not really a pure water surface at all, but one contaminated with oil. It is in fact only after such contamination that an equilibrium of this kind is possible. The volume of oil necessary to contaminate the surface of the water is very small, as we shall see presently; but I want to emphasize the point that, so far as we know, the equilibrium of three surfaces in contact with one another is not possible under any other conditions. That is a fact not generally recognized. In many books you will find descriptions of three bodies in contact, and a statement of the law of the angles at which they meet; that the sides of a triangle, drawn parallel to the three intersecting surfaces, must be in proportion to the three tensions. No such equilibrium, and no such triangle, is possible if the materials are pure; when it occurs, it can only be due to the contamination of one of the surfaces.

These very thin films, which spread on water, and with less freedom on solids also, are of extreme tenuity, and their existence alongside of the lens proves that the water prefers the thin film of oil to one of greater thickness. If the oil were spread out thickly, it would tend to gather itself back into drops, leaving over the surface of the water a film of less thickness than the molecular range.

One experiment by which we may illustrate some of these effects I owe to my colleague, Professor Dewar. It shows the variation in the surface tension of water, due to the presence on it of small quantities of ether. I hold in my hand masses of charcoal, which can be impregnated with ether. The greater part of the surface of the charcoal is covered with paraffin wax, and, in consequence, the ether which has already penetrated the charcoal can easily escape from it again on one side. The result is that the water in the rear of this boat of charcoal will be more impregnated with ether than the part in front, so the mass of charcoal will enter into motion, and the motion will extend over a considerable interval of time. As long as the ether remains in sufficient quantity to contaminate the water in the rear, so long is there a tendency to movement of the mass. The water covered with the film of ether has less tension than the pure water in front, and the balance of tensions being upset, the mass is put in motion. If the nature of the case is such that the whole surface surrounding the solid body is contaminated, then there is no tendency to movement, the same balance, in fact, obtaining as if the water were pure.

Another body which we may use for this purpose is camphor. If we spread some camphor scrapings on a surface of pure water, they will, if the surface is quite clean, enter into vigorous movement, as you now see. This is because the dissolved camphor diminishes the surface tension of the water. But if I now contaminate the water with the least possible quantity of grease, the movements of the camphor will be stopped. I merely put my finger in, and you observe the effect. There is not much poetry about that. A very slight film, perfectly invisible by ordinary means, is sufficient so to contaminate the water that the effect of the dissolved camphor is no longer visible.

I was very desirous to ascertain, if possible, the actual thickness of oil necessary to produce this effect, because all data relating to molecules are, in the present state of science, of great interest. From what I have already said, you may imagine that a quantity of oil required is very small, and that its determination may be difficult. In my experiments,* I used the surface of water contained in a large sponge bath three feet in diameter. By this extension of the surface, I was able to bring the quantity of oil required within the range of a sensitive balance. In Diagram 2 I have given a number of results obtained at various dates, showing the quantity of oil required to produce the effects recorded in the fourth column. Knowing the weight of the oil deposit, and the area of the water surface upon which it was uniformly spread, it was easy to calculate the thickness of the film. It is seen that a film of oil about 1½ millionth of a millimeter thick is able to produce this change. I know that large numbers are not readily appreciated, and I will therefore put the matter differently. The thickness of the oil film thus determined as sufficient to stop the motions of the camphor is one four-hundredth of the wave length of yellow light. Another way of saying the same thing is that this thickness of oil bears to one inch the same ratio that one second of time bears to half a year.

DIAGRAM FIG. 2.

A Sample of Oil somewhat Decolorized by Exposure.

Date.	Weight of Oil. M. grm.	Calculated Thickness of Film in Micro-millimeters.	Effect upon Camphor Fragments.
Dec. 17.	0·40	0·81	No distinct effect.
Jan. 11.	0·52	1·06	Barely perceptible.
Jan. 14.	0·65	1·32	Not quite enough.
Dec. 20.	0·78	1·58	Nearly enough.
Jan. 11.	0·78	1·58	Just enough.
Dec. 17.	0·81	1·63	Just about enough.
Dec. 18.	0·83	1·68	Nearly enough.
Jan. 22.	0·84	1·70	About enough.
Dec. 18.	0·95	1·92	Just enough.
Dec. 17.	0·99	2·00	All movements very nearly stopped.
Dec. 20.	1·31	2·65	Fully enough.
	A Fresh Sample.		
Jan. 28.	0·63	1·28	Barely perceptible.
Jan. 28.	1·06	2·14	Just enough.

When the movement of the camphor has been

* A lecture delivered at the Royal Institution of Great Britain, March 28, 1890.

* *Proc. Roy. Soc.*, March, 1890.

stopped by the addition of a minute quantity of oil, it is possible, by extending the water surface inclosed within the boundary, without increasing the quantity of oil, to revive the movements of the camphor; or, again, by contraction to stop them. I can do this with the aid of a flexible boundary of thin sheet brass, and you see that the camphor recovers its activity, though a moment ago it was quite dead. It would be an interesting subject for investigation to determine what is the actual tension of an oily surface contaminated to an extent just sufficient to stop the camphor movements; but it is not an easy problem. Usually we determine surface tensions by the height to which the liquids will rise in very fine tubes. Here, however, that method is not available, because if we introduce a tube into such a surface, there is no proof that the contamination of the inner surface in the tube is the same as that prevailing outside. Another method, however, may be employed which is less open to the above objection, and that is to substitute for the very fine or capillary tube a combination of two parallel plates open at their edges. We have here two such plates of glass kept from absolutely closing by four pieces of thin metal, inserted at the corners, the plates being held close against these distance pieces by suitable clamps. If such a combination be inserted in water, the liquid will rise above the external level, and the amount of the rise is a measure of the surface tension of the water. You see now the image on the screen.

A is the external water surface; B is the height of the liquid contained between the glass plates, so that the tension may be said to be measured by the distance, AB. If a little oil be now deposited upon the surface, it will find its way between the plates. The fall which you now see shows that the surface tension has been diminished by the oil which has found its way in. A very minute quantity will give a great effect.

When the height of the pure water was measured by 62, a small quantity of oil changed the 62 into 48, and subsequent large additions of oil could only lower it to 38. But after oil has done its worst, a further effect may be produced by the addition of soap. If Mr. Gordon now adds some soap, we shall find that there is a still further fall in the level, showing that the whole tension now in operation is not much more than one-third of what it was at first. This is an important point, because it is sometimes supposed that the effect of soap in diminishing the tension of water is due to merely the formation upon the surface of a layer of oil formed by decomposition of the soap.

This experiment proves the contrary, because we find that soap can do so much more than oil. There is, indeed, something more or less corresponding to the decomposition of the soap and the formation of a superficial layer of oil. But the decomposition takes place in a very peculiar manner, and under such conditions that there is a gradual transition from the soapy liquid in the interior to the oily layer at the top, and not, as when we float a layer of oil on water, two sudden transitions, first from water to oil, and secondly from oil to air. The difference is important, because, as I showed some years ago, capillary tension depends on the suddenness of change. If we suppose that the change from one liquid to another takes place by slow stages, though the final change may be as before, the capillary tension would absolutely disappear.

There is another very interesting class of phenomena due to oil films, which I hope to illustrate, though I am conscious of the difficulty of the task—namely, the action of oil in preventing the formation of waves. From the earliest times we have records of the effect of oil in stilling waves, and all through the middle ages the effect was recognized, though connected with magic and fanciful explanations. Franklin, than whom, I suppose, no soberer inquirer ever existed, made the thing almost a hobby. His attention was called to it accidentally on board ship from noticing the effect on the waves caused by the greasy debris of a dinner. The captain assured him that it was due to the oil spread on the water, and for some time afterward Franklin used to carry oil about with him, so as never to miss a chance of trying an experiment. A pond is necessary to illustrate the phenomena properly, but we shall get an idea of it by means of this trough six feet long, containing water.* Along the surface of the water we shall make an artificial wind by means of a fan,† driven by an electric motor. In my first experiments I used wind from an organ bellows, which is not here available. Presently we shall get up a ripple, and then we will try the effect of a drop of oil put in to windward. I have now put on the drop, and you see a smooth place advancing along. As soon as the waves come up again, I will repeat the experiment.

While the wind is driving the oil away, I may mention that this matter has been tested at Peterhead. Experiments were there made on a large scale to show the effect of oil in facilitating the entrance of ships into harbor in rough weather. Much advantage was gained. But here a distinction must be observed. It is not that the large swell of the ocean is damped down. That would be impossible. The action in the first instance is upon the comparatively small ripples. The large waves are not directly affected by the oil, but it seems as if the power of the wind to excite and maintain them is due to the small ripples which form on their backs, and give the wind, as it were, a better hold of them. It is only in that way that large waves can be affected. The immediate effect is on the small waves, which conduce to that breaking of the large waves which, from the sailor's point of view, is the worst danger. It is the breaking waters which do the mischief, and these are quieted by the action of the oil.

I want to show also, though it can only be seen by those near, the return of the oil when the wind is stopped. The oil is at present driven to one end of the trough;‡ when the wind stops, it will come back, because the oil film tends to spread itself uniformly over the surface. As it comes back, there will be an advancing wave of oil; and as we light the surface very obliquely by the electric lamp, there is visible on the bottom of the trough a white line, showing its progress.

Now, as to the explanation. The first attempt on the right lines was made by the Italian physicist Marangoni. He drew attention to the importance of contamination upon the surface of the water, and to its tendency to spread itself uniformly, but for some reason which I cannot understand, he applied the explanation wrongly.

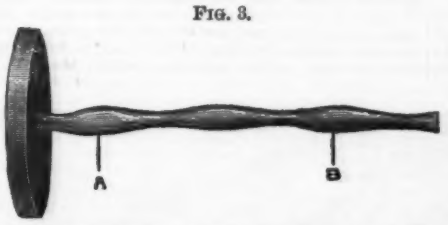
More recently Reynolds and Aitken have applied the same considerations with better success. The state of the case seems to be this: Let us consider small waves as propagated over the surface of clean water; as the waves advance, the surface of the water has to submit to periodic extensions and contractions. At the crest of a wave the surface is compressed, while at the trough it is extended. As long as the water is pure there is no force to oppose that, and the wave can be propagated without difficulty; but if the surface be contaminated, the contamination strongly resists the alternate stretching and contraction. It tends always, on the contrary, to spread itself uniformly, and the result is that the water refuses to lend itself to the motion which is required of it. The film of oil may be compared to an inextensible membrane floating on the surface of the water, and hampering its motion; and under these conditions it is not possible for the waves to be generated unless the forces are very much greater than usual. That is the explanation of the effect of oil in preventing the formation of waves.

The all-important fact is that the surface has its properties changed, so that it refuses to submit to the necessary extensions and contractions. We may illustrate this very simply by dusting the surface of water with sulphur powder, only instead of dispersing the sulphur, as before, by the addition of a drop of oil, we will operate upon it by a gentle stream of wind projected downward on the surface, and of course spreading out radially from the point of impact. If Mr. Gordon will blow gently on the surface in the middle of the dusty region, a space is cleared;* if he stops blowing, the dust comes back again. The first result is not surprising, but why does the dusty surface come back? Such return is opposed to what we should expect from any kind of viscosity, and proves that there must be some force directly tending to produce that particular motion. It is the superior tension of the clean surface. No oil has been added here, but then no water surface is ever wholly free from contamination; there may be differences of degree, but contamination is always present to some extent. I now make the surface more dirty and greasy by contact of the finger, and the experiment no longer succeeds, because the jet of wind is not powerful enough to cleanse the place on which it impinges; the dirty surface refuses to go away, or if it goes in one direction, it comes back in another.

I want now to bring to your notice certain properties of soap solutions, which, however, are not quite so novel as I thought when I first came upon them in my own inquiries.† If we measure by statical or slow methods the surface tension of soapy water, we find that it is very much less than that of clean water. We can prove this in a very direct manner by means of capillary tubes. Here, shown upon the screen, are two tubes of the same diameter, in which, therefore, if the liquids were the same, there would be the same elevation; one tube dips into clean water, and the other into soapy water, and the clean water rises much (nearly three times) higher than the soapy water.

Although the tension of soapy water is so much less than that of pure water when measured in this way, I had some reason to suspect that the cause might be quite different if we measured the tension immediately after the formation of the surfaces. I was led to think so by pondering on Marangoni's view that the behavior of foaming liquids was due to the formation of a pellicle upon their surfaces; for if the change of property is due to the formation of a pellicle, it is reasonable to suppose that it will take time, so that if we can make an observation before the surface is more than say $\frac{1}{100}$ of a second old, we may expect to get a different result. That may seem an impossible feat, but there is really no difficulty about it; all that is necessary is to observe a jet of the substance in question issuing from a fine orifice. If such a jet issues from a circular orifice, it will be cylindrical at first, and afterward resolve itself into drops. If, however, the orifice is not circular, but elongated or elliptical, the jet undergoes a remarkable transformation before losing its integrity. As it issues from the elliptical orifice, it is in vibration, and trying to recover the circular form; it does so, but afterward the inertia tends to carry it over to the other side of equilibrium. The section oscillates between the ellipse in one direction and the ellipse in the perpendicular direction. The jet thus acquires a sort of chainlike appearance, and the period of movement represented by the distance between corresponding points, A, B, Fig. 3, is a measure of the capillary tension to which

FIG. 3.

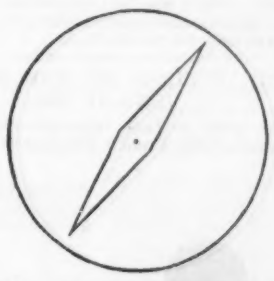


these vibrations of the elliptical section about the circular form are due. A measure, then, of the wave length of the recurrent pattern formed by the liquid gives us information as to the tension immediately after escape; and if we compare the tensions of various liquids, all we have to do is to fill a vessel alternately with one liquid and another, and compare the wave lengths in the various cases. The jet issues from a flask, to which is attached below a tubular prolongation; the aperture is made small in order that we may be able to deal with small quantities of liquid. You now see the jet upon the screen (Fig. 3); it issues from the orifice, it oscillates, and we can get a comparative measure of the tension by observing the distance between corresponding points (A, B).

If we were now to take out the water, and substitute for it a moderately strong solution of soap or saponine, we should find but little difference, showing that in the first moments the tension of soapy water is not very different from that of pure water. It will be more interesting to exhibit a case in which a change occurs. I therefore introduce another liquid, water containing 10 per cent. of alcohol, and you see the wave length is different from before. So this method gives us a means of investigating the tensions of surfaces immediately after their formation. If we calculate by known methods how long the surface has been formed before it gets to the point, B, at which the measurement is concluded, we shall find that it does not exceed $\frac{1}{100}$ of a second.

Another important property of contaminated surfaces is what Plateau and others have described as superficial viscosity. There are cases in which the surfaces of liquids—of distilled water, for example—seem to exhibit a special viscosity, quite different from the ordinary interior viscosity which is the predominant factor in determining the rate of flow through long, narrow tubes. Plateau's experiment was to immerse a magnetized compass needle in water; the needle turns, as usual, upon a point, and the water is contained in a cylindrical vessel, not much larger than the free rotation of the needle requires (Fig. 4). The observation

FIG. 4.



relates to the time occupied by the needle in returning to its position of equilibrium in the meridian, after having been deflected into the east and west positions, and Plateau found that in the case of water more time was required when the needle was just afloat than when it was wholly immersed, whereas in the case of alcohol the time was greater than in the interior. The longer time occupied when the needle is upon the surface of water is attributed by Plateau to an excessive superficial viscosity of that body.

Instead of a needle I have here a ring of brass wire (Fig. 5) floating on the surface of the water. You see

FIG. 5.

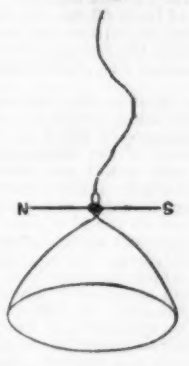
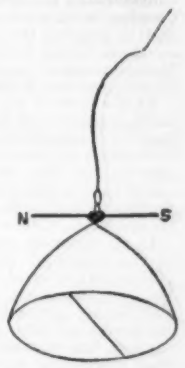


FIG. 6.



upon the screen the image of the ring, as well as the surface of the water, which has been made visible by sulphur. The ring is so hung from a silk fiber that it can turn upon itself, remaining all the while upon the surface of the water. Attached to it is a magnetic needle, for the purpose of giving it a definite set, and of rotating it as required by an external magnet. On this water, which is tolerably clean, when the ring is made to turn, it leaves the dust in the interior entirely behind. That shows that the water inside the ring offers no resistance to the shearing action brought into play. The part of the surface of water immediately in contact with the ring no doubt goes round; but the movement spreads to a very little distance. The same would be observed if we added soap. But if I add some saponine, we shall find a different result, and that the behavior of the dust in the interior of the ring is materially altered. The saponine has stiffened the surface, so that the ring turns with more difficulty; and when it turns it carries round the whole interior with it. The surface has now got a stiffness from which it was free before; but the point upon which I wish to fix your attention is that the surface of pure water does not behave in the same way. If, however, we substitute for the simple hoop another provided with a material diameter (Fig. 6), lying also in the surface of the water, then we shall find, as was found by Plateau in his experiment, that the water is carried round. In this case, it is no longer possible for the surface to be left behind, as it was for the single hoop, unless it is willing to undergo local expansions and contractions of area. The difference of behavior proves that what a water surface resists is not shearing, but expansions and contractions; in fact, it behaves just as a contaminated surface should do. On this supposition, it is easy to explain the effects observed by Plateau; but the question at once arises, Can we believe that all water surfaces hitherto experimented upon are sensibly contaminated? and if yes, Is there any means by which the contamination may be removed? I cannot in the time at my disposal discuss this question fully, but I may say I have succeeded in purifying the surface of the water in Plateau's experiment, until

* The width is eight inches, and the depth four inches. The sides are of glass, the bottom and ends of wood, painted white.

† For this fan and its fittings the institution is indebted to the liberality of the Blackman Ventilating Company.

‡ May, 1890. Any moderate quantity of oil may be driven off to leeward, but if oleate of soda be applied, the quieting effect is permanent.

* This experiment is due to Mr. Aitken.

† I here allude to the experiments of Dupere, and to the masterly theoretical discussion of liquid films by Professor Willard Gibbs.

it behaved like alcohol. It is therefore certain that Plateau's superficial viscosity is due to contamination, as was conjectured by Marangoni.

I must now return to the subject of foam, from which I may seem to have digressed, though I have not really done so. Why does surface contamination enable a film to exist with greater permanence than it otherwise could? Imagine a vertical soap film. Could the film continue to exist if the tension were equal to all its parts? It is evident that the film could not exist for more than a moment; for the interior part, like others, is acted on by gravity, and, if no other forces are acting, it will fall 16 feet in a second. If the tension above be the same as below, nothing can prevent the fall. But observation proves that the central parts do not fall, and thus that the tension is not uniform, but greater in the upper parts than in the lower. A film composed of pure liquid can have but a very brief life. But if it is contaminated, there is then a possibility of a different tension at the top and at the bottom, because the tension depends on the degree of contamination. Supposing that at the first moment the film were uniformly contaminated, then the central parts would begin to drop. The first effect would be to concentrate the contamination on the parts underneath and diminish it above. The result of that would be an increase of tension on the upper parts. So the effect would be to call a force into play tending to check the motion, and it is only in virtue of such a force that a film can have durability. The main difference between a material that will foam and one that will not is in the liability of the surface to contamination from the interior.

I find my subject too long for my time, and must ask you to excuse the hasty explanations I have given at some parts. But I was anxious above all to show the principal experiments upon which are based the views that I have been led to entertain.

THE ECLIPSE OF THE SUN OF JUNE 17, 1890.

On the 17th of June, the inhabitants of entire France and of the French colonies of the northwest

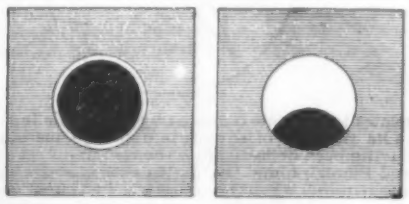


Fig. 2.—ANNULAR PHASE UPON THE EASTERN MEDITERRANEAN, AND PARTIAL PHASE OBSERVED AT PARIS.

of Africa might have witnessed an eclipse, which, although but a partial one to them, was nevertheless of considerable interest. In fact, it was annular for all peoples living upon a zone of from 60 to 120 miles in width, ranging from the Gulf of Guinea as far as to southern China and traversing the Sahara, the eastern Mediterranean, the southwest of Asia, the chain of the Himalayas and Thibet.

At the time of its passage between the sun and the earth our satellite had a very small diameter, because, four days afterward, at its apogee of the 21st of June, it reached its greatest distance of the entire year. It was due to this that its disk could not completely cover that of the sun, although the latter's was at that moment very small, because the earth was passing to its aphelion, which is reached on the 3d of July.

In all quarters, even in the most favored places, and at the epoch of the grand phase, there projected a ribbon of glistening light, which prevented the aureolas, protuberances, etc., from being seen. There was a sufficiently perceptible diminution of light to allow barbarous peoples who were witnesses of the phenomenon, but who were unable to foretell it, to perceive that something extraordinary was taking place upon the sun's disk. As for Paris and the other large cities of France, the part obscured was not of sufficient importance to allow the diminution of the light to attract the attention of persons who were not forewarned.

The phases of the eclipse were observed in all our public and private astronomical establishments, the number of which is daily increasing in the most satisfactory manner.

Mr. Janssen, the director of the Meudon observatory, who has just returned from a long expedition to the Sahara, where he has continued his studies upon the solar atmosphere, confided to an assistant the duty of following the eclipse at the place where it exhibited itself in the most instructive manner, that is to say, at Candia, which may be considered as the center of it.

This eclipse of the sun, which bears the number 7,383 in Oppolzer's great catalogue, was the 219th of the century; but it would not have been possible to observe more than the tenth part of this number within our walls, even had the sky been favorable, which is not very often the case.

However this may be, the first point of the globe touched by the cone of the penumbra is situated in the equatorial ocean, to the north of Ascension island, and the last is in the Indian ocean, to the north of the island of Ceylon.

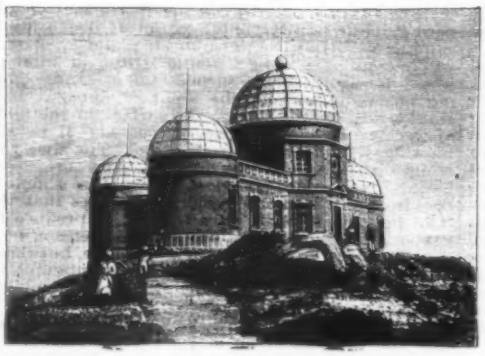
The first contact occurred at 7 h. 4 m. in the morning, in mean time of Paris, and the second at 1 h. and 4 m. in the afternoon. The phenomenon, therefore, lasted just six hours for the whole earth. It was but two hours and some minutes less than the largest duration possible, under the most favorable circumstances. During this time, the earth revolved 90 degrees around its polar axis, so that the local hours of the phases of the eclipse were all affected by such revolution.

But the cone of the penumbra that the moon carries along behind it sweeps the earth with a velocity much greater, since, despite this so notable a displacement, we find a little more than 97 degrees of longitude between the first point situated to the west and the last situated to the east—that is to say, between the first and last contact.—*La Nature.*

THE TANANARIVE OBSERVATORY.

We present herewith a view of the Tananarive observatory (Madagascar) from a photograph kindly sent to us by Mr. Mascart, after a communication made by him to the Academy of Sciences.

This remarkable scientific establishment was constructed by Father Colin, at the altitude of 4,600 feet, on the summit of a hill, situated at a few miles from Tananarive, on the island of Madagascar, and not far from the ruins of the ancient village of Ambohidempona. It is a building of dressed stone, provided with four cupolas. Owing to the initiative of Mr. Le Myre de Vilers, then resident-general of Madagascar, it was possible to build this edifice without special credit, by means of resources furnished by persons or associations desirous of giving their aid in the development of French influence in this country.



TANANARIVE OBSERVATORY.

In addition to astronomical observations, Father Colin has organized a regular service of meteorological ones, with secondary stations in various parts of the island—at Tamatave, Fianarantsoa, Fort Dauphin, Majunga, Diego-Suarez, Mananjary, and Arivonimano. A magnetograph is in course of installation.

This establishment will furnish science with the most valuable data upon the as yet not well known climate of Madagascar, and upon the general run of meteorological phenomena in the adjacent seas. The Academy of Sciences has given it its encouragement, and Mr. Mascart has justly called the attention of the friends of science to it.—*Le Genie Civil.*

[Science.]

A STONY METEORITE FROM WASHINGTON COUNTY, KAN.

Having seen press dispatches from Washington, the county seat of Washington county, Kan., announcing the fall of an aerolite near that town on Wednesday, June 25, I visited that county at the earliest possible opportunity, for the purpose of ascertaining the facts.

I found them to be as follows, and verified by a multitude of witnesses: At about ten minutes before one o'clock on the afternoon of June 25, the sky being free from clouds, a strange noise was heard by thousands of people residing in the counties of Washington, Republic, Cloud, Clay, Riley, Pottawatomie, and Marshall, in Kansas, and in the counties of Thayer, Jefferson, and Gage, in Nebraska. The same noise was heard by hundreds of people in counties more distant than those mentioned.

The descriptions given me of the character of this strange sound were exceedingly various. Mr. E. F. Woodruff, of Clifton, fully twenty-five miles from the place where the meteor struck the ground, stated to me that, while standing on the front porch of his hotel after dinner, a few minutes before one o'clock, his attention was attracted by a rumbling sound like thunder, which began gently and increased in power to a maximum, rising even above the din of a Missouri Pacific railroad train which passed within a few rods during the continuance of the phenomenon. The sound appeared to him to come from the zenith, and to continue for two or three minutes, gradually fading away and being at no time of an explosive character.

Mr. John Yates, of Grant township, more than fifty miles from Washington, on the contrary, heard the sound of the flying meteor, and described it as like the report of a hundred pound cannon, which shook his house and jarred the windows. He at first supposed the disturbance to be produced by the explosion of a boiler at Gann's elevator, in the neighboring town of Riley. Mr. Sprengle, father of L. J. Sprengle, of the *Washington Republican*, not only heard the meteor, but looking toward the zenith, shading his eyes from the glare of the sun, saw just below that luminary a swiftly moving mass of waving mist, followed by a double trail of bluish smoke.

This aerolite was seen by many observers at a much greater distance from the place where it fell. Mr. D. C. Ruth, of Halstead, Harvey county, Kansas (a hundred and thirty miles distant in a direction slightly west of south), saw a large fireball moving through the atmosphere at a few minutes before one o'clock on June 25. It was also seen at Topeka (eighty-seven miles southeast) by a neighbor of H. R. Hilton, Esq. It was reported by the newspapers as having been both heard and seen at Atchison (a hundred and two miles distant) and at Leavenworth (a hundred and fifteen miles distant), the last two places being in a direction east-southeast from Washington. A note received from C. W. Marsten, Esq., of Cedar Junction (a hundred and thirty miles southeast from Washington) makes the following statements: "An aerolite passed in sight of this place on Wednesday, June 25, at about 1 p. m. Of the several who saw it, Mrs. John D. Randall says of it, 'It was a ball of fire as large as a table. It had a trail like a comet, and it wabbled like a kite.'"

At Beatrice, in Nebraska, forty miles northeast of Washington, it was reported as a brilliant meteor passing over the city from north to south, leaving a distinct fiery trail behind. The fact that at places to the north of the point of collision with the earth the meteor appeared to be moving toward the south, while at places to the south it appeared to be moving toward the north, corroborates the testimony given by the nearly perpendicular sides of the hole it made in the ground, that it passed through the atmosphere from the vicinity of the zenith.

The meteor reached the ground, and buried itself out of sight, four feet deep, below the eighteen inches of upper alluvium in the underlying shaly clay or "gumbo." This spot is located three miles and a half north of Washington, in Farmington township, about a hundred yards from the north and south road, near the southwest corner of the northwest quarter of the southwest quarter of Section 13, township 2, Range 3, east of the sixth principal meridian. The farm belongs to Mrs. Lydia V. Kelsey, of Iowa, and was rented by Mr. J. H. January, who was on that day breaking the prairie sod. The noon hour had not quite expired, and Mr. January was underneath his wagon making some repairs, when he heard the sound of the approaching meteor, and came out to ascertain the cause of the disturbance. He had hardly gained the erect position, when the meteor struck the ground only a few rods distant, throwing up the earth to a height of forty feet into the air and outward for about twenty-five feet. It was also seen to strike the earth by Miss Guild, a teacher, who was returning to her home in the country after her forenoon's attendance at the Washington County Normal Institute, and was at the instant driving her horse and cart along the north and south road, only a hundred yards distant. As soon as her frightened and trembling horse had recovered from the shock, Miss Guild drove to the spot, which she reached at the same moment with Mr. January. As soon as Mr. January had calmed his frightened horses, he began to dig for the aerolite; and with the help of a neighbor, Mr. J. D. Foster, and three other men, he reached the upper surface of the stone in one hour, but it required three hours to remove the mass from its bed, it was so firmly held in place by the compressed "gumbo." The stone was not hot when reached, which may be explained by the fact that it seems to have passed through the minimum amount of air from a direction but a few degrees south of the zenith. It was covered, however, by the usual burned crust. The stone was found to have been cracked, doubtless by the force of collision acting upon a body already under the disrupting strain of unequal temperatures. The entire mass weighed a hundred and eighty-eight pounds, and was divided by this crack into two portions, weighing respectively a hundred and forty-four and forty-four pounds.

The smaller mass was soon subjected to a process of sledge hammering by the hundreds of people who almost immediately visited the spot. Nearly every citizen of Washington has in his pocket a small fragment of the stone. The portion remaining, weighing a hundred and forty-four pounds, is somewhat wedge-shaped, in dimensions nineteen by seventeen inches at the base. The writer obtained from Mr. J. D. Foster for analysis a fragment weighing two pounds and a quarter.

In color the stone is dark slate, resembling a compact traprock. An analysis has been made by Mr. E. E. Slosson, assistant in our chemical department, whose preliminary report is as follows:

"The stone is of a gray color, and in texture resembles porphyry. A few metallic grains are all that can be distinguished with the naked eye. Under a microscope by chemical treatment the following minerals can be detected:

"1. A white crystalline silicate, insoluble, forming about half the mass of the whole; probably enstatite or a similar bisilicate of the pyroxene group.

"2. A black translucent crystalline silicate intermingled with the above, though less in amount. It is decomposed by *aqua regia*, and contains iron; probably a uni-silicate of the olivine type. These two minerals are in some fragments arranged in alternate microscopic layers of equal thickness.

"3. Malleable nickeliferous iron in small irregu-

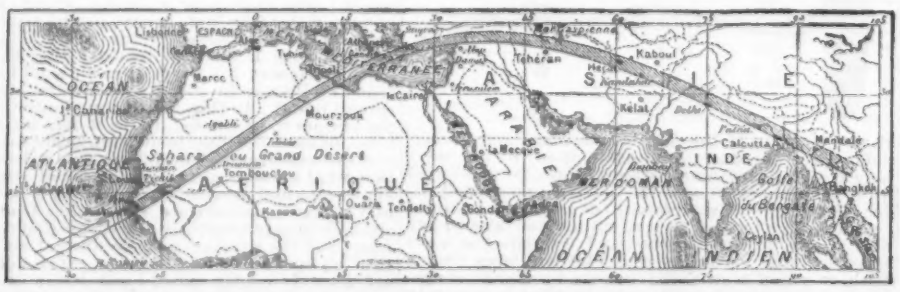


Fig. 1.—MAP OF THE ZONE IN WHICH THE ECLIPSE OF THE SUN OF JUNE 17TH WAS ANNULAR.

lar masses, intimately mixed with troilite and the silicates.

"4. Troilite or pyrrhotite in microscopic particles disseminated through the whole rock, estimated from sulphur to be about 10 per cent.

"5. Chromite, distinguishable as small black magnetic crystals in the residue after treatment with the acids.

"6. A few scattered silicious crystals, yellow and red; too small to determine, probably olivine.

"The following is an approximate analysis of a small fragment: Metallic iron (with part of the iron in silicates), 14·953 per cent.; troilite, 10; soluble silicates (olivine), 25·147; insoluble silicates (enstatite), 49·9; nickel and chromite, undetermined; specific gravity of fragment weighing two pounds and a half, 3·48, water at 25° C."

The hundred and forty-four pound mass has also been bought by the writer and Professor F. W. Cragin, of Washburn College, Topeka, in equal partnership, for the benefit of the museums of their respective institutions. F. H. SNOW.

University of Kansas, Lawrence, Kan., July 7.

A CHAT ABOUT WORMS.

By the Rev. HILDERIC FRIEND, F.L.S.

WHEN a famous naturalist presented the public a few years ago with a volume entirely devoted to the doings of earth worms, a cry of surprise was heard on every hand. We never thought that so much could be said about a worm! Those who think that Darwin knew all that could be known about these despised creatures will probably regard us with suspicion if we say that he only touched the very fringe of a great and entrancing subject, and that his knowledge was limited to the habits of one or two species out of a vast number, every one of which has just as much to teach us, if only we were as willing and able to learn as Darwin was. I can imagine a good many people who think they have some scientific information telling us that they did not know we had more than two or three species of worms in England, and that their appearance and habits are so similar that when you know something about the commonest, you have a key to everything worth knowing. Such was the state of our information only a very few years ago, and it is only within very recent years that we have been made aware of the existence, both at home and abroad, of an enormous number of species of Annulosa, or earth worms, and their allies. There are still undoubtedly scores of worms undiscovered, for in the vast empire of China, the continent of Africa, the untrodden wastes of Australia, and the unexplored regions of many lands near and far, there must be hidden under the soil myriads of creatures whose very existence we have never suspected. Every year new discoveries are being made, and even in our own country the helminthologist is able from time to time to whet his appetite for further exploration, by turning up an undescribed species. Although many new indigenous species cannot well be expected to reward the search of the worm collector at home, the ever-increasing acreage of glass and greenhouse, with the constant introduction of new plants from little known regions of the globe, afford favorable opportunities for worm study to those who have the good fortune to be able to visit conservatories and hothouses whenever they please.

It may be asked, where shall we find materials for the study of worms, and how shall we know them when found? In reply to the first question it may be stated that there is scarcely a place where they may not be found.

If we take the worms in their widest sense, as corresponding with the annelida, we may say that they are to be found almost everywhere. Some are found attached to marine algæ (*Spirorbis*), or building their calcareous homes on the shells of the mollusca (*Serpula*), throwing up their tubes here and there along the sea coast (*Terrebella*), or in large masses at low water mark (*Sabellaria*), burrowing in the sands down to midtides (*Arenicola*) or in the meadows, pastures, or the open country (*Lumbricus*), lying under stones in streams (*Allolobophora*), or on the margins of ponds and locks (*Allurus*), and enjoying the fat living of a manure heap (*Brandling*), or surprising the florist in his greenhouse (*Megascolex*), not to mention other localities or genera. As I have found the whole of these during a single season in Cumberland, I am not holding out any false hopes to the young naturalist when I say that, if he has the pleasure of living within reach of the sea shore, he may in one year collect typical specimens of all the principal genera of British annelids. It may be remembered that they are about equally divided between sea and land, and that of the inland species a goodly number are partial to paludal situations—lying under stones or in the mud.

Now comes the tug of war. How can I determine my captures? This, it must be admitted, is not always easy; but then all real research involves some amount of labor, and sometimes of disappointment. Let us say, however, that it is always best to begin with the well known, and proceed to the less known or altogether unknown. Many books dealing with the subject in a partial manner are available, but the student must always fall back, more or less, upon his own resources. For example, the Lugworm (*Arenicola piscatorum*) of the sea shore is so well known that when once seen in a book or in a state of nature it will never be forgotten, and as every fisherman along our sandy shores digs this creature out for bait, it is always possible to procure it in abundance. The little coiled up shells or tubes, again, which are found encrusting almost every bit of dead seaweed cast up on our shores, are so well known (*Spirorbis nautiloides*, Link, and *S. lucidus*, Mont.) that they will occasion no difficulty. It is when he comes to the worms which build no homes, and at first sight have no distinctive characters, that the student meets his real difficulties.

Let us confine ourselves to what are best understood as earthworms. Here we have at the outset for our guidance the common Lumbricus, whose form and habits are familiar to every one. Whether we dig in the garden, mow the lawn, or plough the field, whether we watch the birds in search of their breakfast, or ourselves seek the worm as a bait for fishing, we recognize the common worm without difficulty, although we should not find it an easy matter to specify what are the "signs" by which we identify it. A little careful attention to its external structure, however, will afford us certain characters which will be useful. We observe the number, position and shape of the bristles or hairs which exist on each of the body segments; the position and appearance of the mouth and clitellum (Fig. 5), the color of the creature when clean, as well as the general form of the entire animal. If we descend to microscopical details, we pass beyond the region of what is popular, and our chat becomes professorial. Now, with these general principles in mind, we can pass from the common worm (*Lumbricus terrestris*) to the green worm (*L. viridis*), which is found under stones in cattle fields, and distinguished by its color. The other distinctions as well as the name aliases are omitted because the worms are being rearranged by the systematists, and until their terminology assumes some definite form, the old and established terms had better be retained to avoid confusion. Another British worm (*L. anatomicus*) is distinguished from the foregoing by the marked difference which exists between the two extremities of the body. It may be noted that in works on Biology by Huxley and Martin, Lloyd Morgan, Harvey Gibson and others, the common worm is selected as a type. Differing widely in external appearance from the foregoing is the pretty Brandling (*L. fœtida*), a favorite bait for trout. The color is a ruddy brown, with alternate bands of yellow, and when the animal is disturbed or placed in spirits it exudes a pungent yellow fluid of a striking character. The fluid which some other worms are able to produce is sometimes pure white (*L. mucosa*); and the whole subject of worm fluid is worthy particular attention, as it would seem that the power to exude such a protective material is analogous to the ability to make a more enduring protection in the shape of shells and cases on the part of other annelids.

The worm hunter will turn over every likely stone or rubbish heap which comes in his path, and in so doing will be sure to meet with some interesting prizes. By the sides of streams there are numerous semi-aquatic worms of a more stunted form than that which the earthworm usually assumes. One of these worms bears the name of Allolobophora, and is by no means rare. In similar situations, and on the margins of ponds, tarns and lochs, a curious and instructive worm with a square contour (*Allurus tetraedrus*, Fig. 1), instead of a round or oval shape, is often met with. I have taken it plentifully in May near Carlisle, along with other worm-like creatures which love the same locality, but have a flat ventral surface and a suctorial organ on the posterior as well as the anterior extremity, showing that they belong to sub-class Hirudinea, which contains the leeches or suctorial annelids.

When the collector has exhausted his hunting grounds he may turn with some amount of hope to the greenhouses and hothouses of his friends, and if these are frequently receiving new consignments of foreign plants, there is little doubt but that in a short time some new form will present itself. I have in such places procured specimens of a very curious worm of a stiff habit, defiant disposition, and with a quite un-English air (Fig. 3). The special peculiarity of this genus (*Megascolex*), so far as external characteristics are concerned, is the arrangement of the setæ or bristles, which form a perfect ring or whorl around each segment of the body (Fig. 4 *a*). And here in conclusion it may be as well to note that the arrangement of setæ is a feature which really lends itself to the discrimination of genera, and as it usually accompanies other generic characteristics, it is frequently referred to by systematists as one of the external notabilia. If the earth worm, for example, be examined, it will be found that there are eight bristles on each segment, which are arranged in pairs on the ventral half of the body. In Allurus the spines are arranged in pairs on the four angles of the square-shaped body, while they are about equidistant on both ventral and dorsal surfaces in Allolobophora. This latter arrangement leads the way to Megascolex, where the setæ are found all around the segments, but more numerous than in the last genus. For the internal characteristics reference must be made to the papers of Beddard, Benham and others; while the chatty paper of the late Frank Buckland, in his "Natural History of British Fishes," may appropriately be read as a sequel to the foregoing. I give a list of the species and localities, which form the critical apparatus for this article, elsewhere.—*Hardwicke's Science Gossip.*

FIG. 1.

FIG. 2.

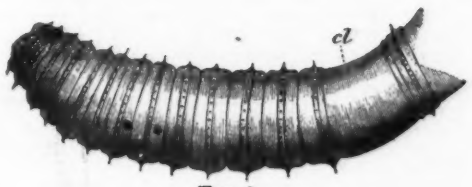


FIG. 3.

FIG. 4.

FIG 5.

AN INFANT PRODIGY.

By S. V. CLEVENGER, M.D., Chicago.

Two little colored children were reciting the multiplication table at their home, in a little cabin in Texas, as they had repeatedly done before, and one of them asserted that four times twelve was fifty-eight, whereupon a thirteen months old baby, Oscar Moore, who had never spoken before, corrected the error by exclaiming: "Four times twelve are forty-eight!" with the emphasis on the forty-eight. There was consternation in that humble home until the family became reconciled to the "freak."

I publicly exhibited him to the physicians of Chicago, at the Central Music Hall, in 1888.

Oscar was born blind, and, as frequently occurs in such cases, the touch sense compensatingly developed extraordinarily.

It was observed that after touching a person once or twice with his stubby baby fingers, he could, thereafter, unfailingly recognize and call by name the one whose hand he again felt. The optic sense is the only one defective, for tests reveal that his hearing, taste and smell are acute, and the tactile development surpasses in refinement.

But his memory is the most remarkable peculiarity, for when his sister conned her lessons at home, baby Oscar, less than two years old, would recite all he heard her read.

Unlike some idiot *savants*, in which category he is not to be included, who repeat, parrot-like, what they have once heard, baby Oscar seems to digest what he hears, and requires at least more than one repetition of what he is trying to remember, after which he possesses the information imparted and is able to yield it at once when questioned.

It is not necessary for him to commence at the beginning, as the possessors of some notable memories were compelled to do, but he skips about to any required part of his repertoire.

He sings a number of songs and counts in different languages, but it is not supposable that he understands every word he utters. If, however, his understanding develops as it promises to do, he would become a decided polyglot.

He has mastered an appalling array of statistics, such as the areas in square miles of hundreds of countries, the population of the world's principal cities, the birthdays of all the presidents, the names of all the cities of the United States of over 10,000 inhabitants and a lot of mathematical data.

He is greatly attracted by music, and this leads to the expectation that he may rival Blind Tom when more mature.

In disposition he is very amiable, but rather grave beyond his years. He shows great affection for his father, and is as playful and happy as the ordinary child.

He sleeps soundly, has a good, childish appetite and appears to be in perfect health. His motions are quick but not nervous, and are as well co-ordinated as in a child of ten. In fact, he impresses one as having the intelligence of a much older child than three years (now five years), but his height, dentition and general appearance indicate the truthfulness of the age assigned.

An evidence of his symmetrical mental development appears in his extreme inquisitiveness. He wants to understand the meaning of what he is taught, and some kind of an explanation must be given him for what he learns. Were his memory alone abnormally great and other faculties defective, this would hardly be the case, but if so, it cannot at present be determined.

His complexion is yellow, with African features, flat nose, thick lips, but not prognathous, superciliary ridges undeveloped, causing the forehead to protrude a little. His head measures nineteen inches in circumference, on a line with the upper ear tips, the forehead being much narrower than the occipito-parietal portion, which is noticeably very wide. The occiput protrudes backward, causing a forward sweep of the back of the neck.

From the nose root to the nucha over the head he measures thirteen and one-half inches, and between upper ear tips across and over the head, eleven inches, which is so close to the eight and ten inch standard that he may be called mesocephalic.

The bulging in the vicinity of the parietal bosses accords remarkably with speculations upon the location of the auditory memory in that region, such as those in the *American Naturalist*, July, 1888, and the fact that injury of that part of the brain may cause loss of memory of the meaning of words. It may be that the premature death of the mother's children has some significance in connection with Oscar's phenomenal development. There is certainly a hypernutrition of the parietal brain with atrophy of the optic tract, both of which conditions could arise from abnormal vascular causes, or the extra growth of the auditory memory region may have deprived of nutrition, by pressure, the adjacent optic centers in the occipital brain.

The otherwise normal motion of the eyes indicates the nystagmus to be functional.

Dr. Henry Gradle, the oculist, examined Oscar's eyes, and kindly furnishes the following report:

"When addressed, there is conjugate deviation of the eyeballs to the right and somewhat downward, but motion is possible in every direction with perfect parallelism of the two eyes. There is no strabismus. Nystagmus occurs with the eye movements, especially when toward the left.

"There is no evidence of sight. He appears to be absolutely blind. The pupils are of medium width and immobile, rather less than the width of total blindness, nor do they dilate freely with homatropine. The ophthalmic disks are small and have undergone pure white athropy, not cupped. Veins and arteries of fundus are normal in size (a remarkable condition in association with atrophy). There are whitish streaks of degeneration in the retinal centers, but no pigmentary or other anomalies. It seems likely that the blindness is due to prenatal hemorrhage near the optic chiasm."

Oscar Moore, the infant prodigy, was born August 19, 1885, in Waco, Texas. His father, Henry Moore, was born in Lawrence county, East Tennessee, in the year 1836. Henry's mother, Ellen Moore, lives in that region, where she also was born about the year 1818. Ellen's mother was a full blooded African, but her father was a white man, named McBroom. She was therefore a mulatto. Her hair was straight and black.

Ellen's husband, the father of Henry, was quarter white. Henry and his mother were slaves, owned by a planter, named Merriam, who sold Henry at the age of twelve years to a negro trader, who resold him to a Dr. Harrison, near Aberdeen, Monroe county, Mississippi, with whom he lived until emancipated at the close of the war. Henry then went to McLennan county, Texas, in 1872, and married a widow named Fanny Thompson, who had two children by her former husband. One of these boys died hydrocephalic in infancy; the living one, born in 1870, is a sprightly young man, fairly educated, who teaches a primary school, and enjoys quite a local reputation as a singer.

Henry and Fanny Moore have had eight children, five boys and three girls, all of whom died probably of tuberculosis excepting two girls and Oscar, who was the seventh child.

Fanny, the mother, is a mulatto, with three brothers and two sisters living in Waco, Texas. She reads a little, but did not learn to write, while her brothers and sisters are but little better instructed. Henry writes and reads a little, and has good common sense. Fanny's other two children by Henry are not remarkable in any particular.

Sudden exaltation of the memory is often the consequence of grave brain disease, and in children this symptom is most frequent. Pritchard, Rush, and other writers upon mental disorders, record interesting instances of remarkable memory increase before death, mainly in adults, and during fever and insanity. In simple mania the memory is often very acute. Romberg tells of a young girl who lost her sight after an attack of smallpox, but acquired an extraordinary memory.

He calls attention to the fact that the scrofulous and rachitic diatheses in childhood are sometimes accompanied by this disorder.

Winslow notes that in the incipient state of the brain disease of early life connected with fevers, disturbed conditions of the cerebral circulation and vessels, and in affections of advanced life there is often witnessed a remarkable exaltation of the memory which may herald death by apoplexy.

Not only has the institution of intelligence in idiots dated from falls upon the head, but extra mentality has been conferred by such an event. Pritchard tells of three idiot brothers, one of whom after a severe head injury brightened up and became a barrister, while his brothers remained idiotic. "Father Mabillon," says Winslow, "is said to have been an idiot until twenty-six years of age, when he fractured his skull against a stone staircase. He was trepanned. After recovering, his intellect fully developed itself in a mind endowed with a lively imagination, an amazing memory, and a zeal for study rarely equaled."

Such instances can be accounted for by the brain having previously been poorly nourished by a defective blood supply, which defect was remedied by the increased circulation afforded by the head injury.

It is a commonly known fact that activity of the brain is attended with a greater head circulation than when the mind is dull, within certain limits. Anomalous development of the brain through blood vessels, affording an extra nutritive supply to the mental apparatus, can readily be conceived as occurring before birth, just as aberrant nutrition elsewhere produces giants from parents of ordinary size.

There is but one sense defect in the child Oscar, his eyesight absence, and that is atoned for by his hearing and touch acuteness, as it generally is in the blind.

Spitzka and others demonstrate that in such cases other parts of the brain enlarge to compensate for the atrophic portion which is connected with the functionless nerves. This, considered with his apparently perfect mental and physical health, leaves no reason to suppose that Oscar's extravagant memory depends upon disease any more than we can suspect all giants of being sickly, though the anomaly is doubtless due to pathological conditions.

Of course there is no predicting what may develop later in his life, but in any event science will be benefited.

It is a popular idea that great vigor of memory is often associated with low grade intelligence, and cases such as Blind Tom, and other "idiot *savants*," who could repeat the contents of a newspaper after a single reading, justify the supposition. Fearon, on "Mental Vigor," tells of a man who could remember the day that every person had been buried in the parish for thirty-five years, and could repeat with unvarying accuracy the name and age of the deceased and the mourners at the funeral. But he was a complete fool. Out of the line of burials he had not one idea, could not give an intelligible reply to a single question, nor be trusted even to feed himself.

While memory development is thus apparent in some otherwise defective intellects, it has probably as often or oftener been observed to occur in connection with full or great intelligence.

Edmund Burke, Clarendon, John Locke, Archbishop Tillotson and Dr. Johnson were all distinguished for having great strength of memory. Sir W. Hamilton observed that Grotius, Pascal, Leibnitz and Euler were not less celebrated for their intelligence than for their memory. Ben Jonson could repeat all that he had written and whole books he had read.

Themistocles could call by name the 20,000 citizens of Athens. Cyrus is said to have known the name of every soldier in his army. Hortensius, a great Roman orator, and Seneca had also great memories.

Niebuhr, the Danish historian, was remarkable for his acuteness of memory. Sir James Mackintosh, Dugald Stewart and Dr. Gregory had similar reputations.

Nor does great mental endowment entail physical enfeeblement; for, with temperance, literary men have reached extreme old age, as in the cases of Klopstock, Goethe, Chaucer; and the average age attained by all the signers of the American Declaration of Independence was 64 years, many of them being highly gifted men, intellectually.

Thus in the case of the phenomenal Oscar it cannot be predicted that he will not develop, as he now promises to do, equal and extraordinary powers of mind, even though it would be rare in one of his racial descent; and in the face of the fact that precocity gives no assurance of adult brightness, for it can be urged that John Stewart Mill read Greek when four years of age.

The child is strumous, however, and may die young. His exhibitors, who are coining him into money, should seek the best medical care for him, and avoid surcharging his memory with rubbish. Proper cultivation of his special senses, especially the tactile, by competent teachers, will give Oscar the best chance of developing intellectually and acquiring an education in the proper sense of the word.—*Alienist and Neurologist.*

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